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# Director's Discretionary Fund Report for FY 1992

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National Aeronautics and  
Space Administration



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# **Director's Discretionary Fund Report for FY 1992**

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May 1993



National Aeronautics and  
Space Administration

**Ames Research Center**  
Moffett Field, California 94035-1000



# INTRODUCTION

The Director's Discretionary Fund (DDF) at Ames Research Center was established to fund innovative, high-risk projects in basic research that are essential to our future programs but otherwise would be difficult to initiate. Summaries of individual projects within this program are compiled and issued by Ames each year as a NASA Technical Memorandum.

These summaries cover 45 projects (both final and ongoing) in Fiscal Year 1992.

The contents are listed alphabetically according to the last name of the primary investigator. Following the narrative reports, an appendix contains a brief description with the financial distribution and status of each of the projects.

Any questions can be addressed to an investigator directly.

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# Feasibility Study for an X-ray Diffractometry Instrument with X-ray Fluorescence Capabilities for Remote Planetary Missions

## Investigator(s)

David F. Blake, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Friedemann Freund, Ames Research Center,  
Moffett Field, CA 94035-1000  
Charles Bryson, Surface Interface, Inc.,  
Mountain View, CA 94041

## Objectives of the study

One of the most important aspects of a planetary surface is its mineralogy. Suites of minerals on a planetary surface can be used to identify past and present climatic conditions, sedimentary processes, and impacts of exogenous material. More than chemical data, mineralogical data are linked to surficial conditions and processes which can be used to elucidate present and past conditions of the atmosphere, the surface, the crust, and occasionally the deep interior of a planet or planetesimal. Despite the power of mineralogy as a descriptive and predictive tool for planetary exploration, diffraction methods have not been used to date on planetary missions. Indeed we know very little about the surface mineralogy of any large solar system bodies save the Earth and its moon. Even on the Moon, broader mineralogic exploration is needed in the searches for either hydrated minerals at the poles, or the abundance and distribution of ore minerals to support a permanent colony on the Moon's surface.

The objectives of this study are to design, fabricate, and test a breadboard prototype of a combined X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) instrument suitable for planetary missions. The information that this instrument collects from a sample (spacings between atomic planes in crystal structures and major element composition) will allow the mineralogic identification of surface soils and other unconsolidated fine-grained samples. The goal of this research is to demonstrate the merit of the analytical technique and find a geometry and design which would be feasible for a flight instrument.

## Progress and results

The geometry of the proposed camera is shown in figure 1. X-rays will be generated in an X-ray tube (1)

and travel to a  $\beta$ -filter and collimator (2). Collimated, monochromatic X-rays then strike the thin-film support and sample material (3). As the monochromatic X-rays strike the sample, a variety of interactions takes place. The two interactions of interest are coherent Bragg diffraction and secondary X-ray fluorescence. Diffracted primary beam X-rays and secondary fluorescence X-rays will strike an X-ray energy-dispersive CCD detector (4) and be detected. Once a sufficient number of X-rays have been recorded, an X-ray diffraction pattern can be produced by displaying an image made only of X-rays having the energy of the primary X-ray beam. An X-ray fluorescence analysis can be obtained by summing all of the X-rays recorded by the CCD into a multichannel analyzer and subtracting out those X-rays having the energy of the primary beam.

At the present time, our test bed for the instrument consists of an X-ray generator fitted with a standard Cu X-ray source and a microfocus X-ray camera. We have been using X-ray sensitive photographic film to study the diffraction geometry of the device. The X-ray fluorescence analysis capability cannot be investigated until our CCD camera is completed (work is in progress at the present time). Figure 2 shows preliminary results from the microfocus camera. The energy-dispersive X-ray analyses shown in the figure were obtained from the same samples using an electron microscope, and are shown for illustration only. From these preliminary results, the utility of the technique is apparent. Using standard X-ray fluorescence analyses, calcium oxide is indistinguishable from calcium carbonate. However, the diffraction patterns from the samples are strikingly different and can be identified by inspection. Differences can be readily found between a variety of other chemically similar materials, including silica phases (quartz, opal-A, opal-CT, and high-pressure phases such as stishovite), carbonates (aragonite, calcite, vaterite), Mars soil analogs (palagonite, iron-rich smectite).

The above diffraction results were obtained using film methods. We have identified a CCD detector with the desired X-ray sensitivity and Energy-Dispersive X-ray capability, and an X-ray camera is presently being assembled by Princeton Instruments Corp. The breadboard instrument will be completed and operational within 4 months.

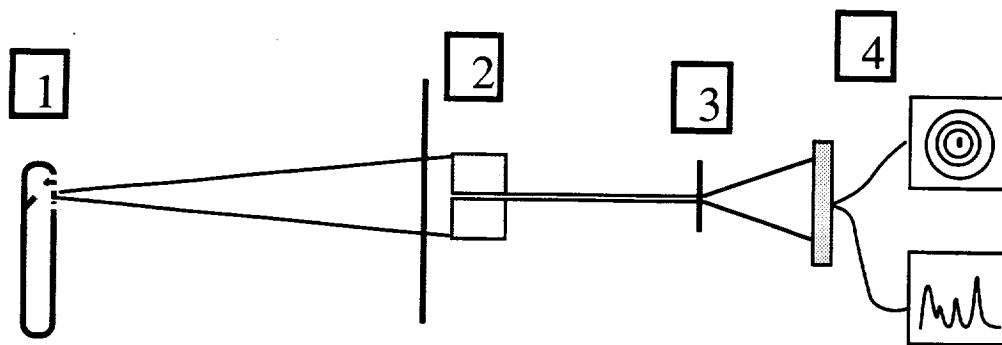


Figure 1. Diagram of XRD/XRF instrument. (1) X-ray source, (2)  $\beta$ -filter and collimator, (3) sample holder and thin film sample, (4) CCD detector showing schematic rendition of XRD and XRF measurements from the sample.

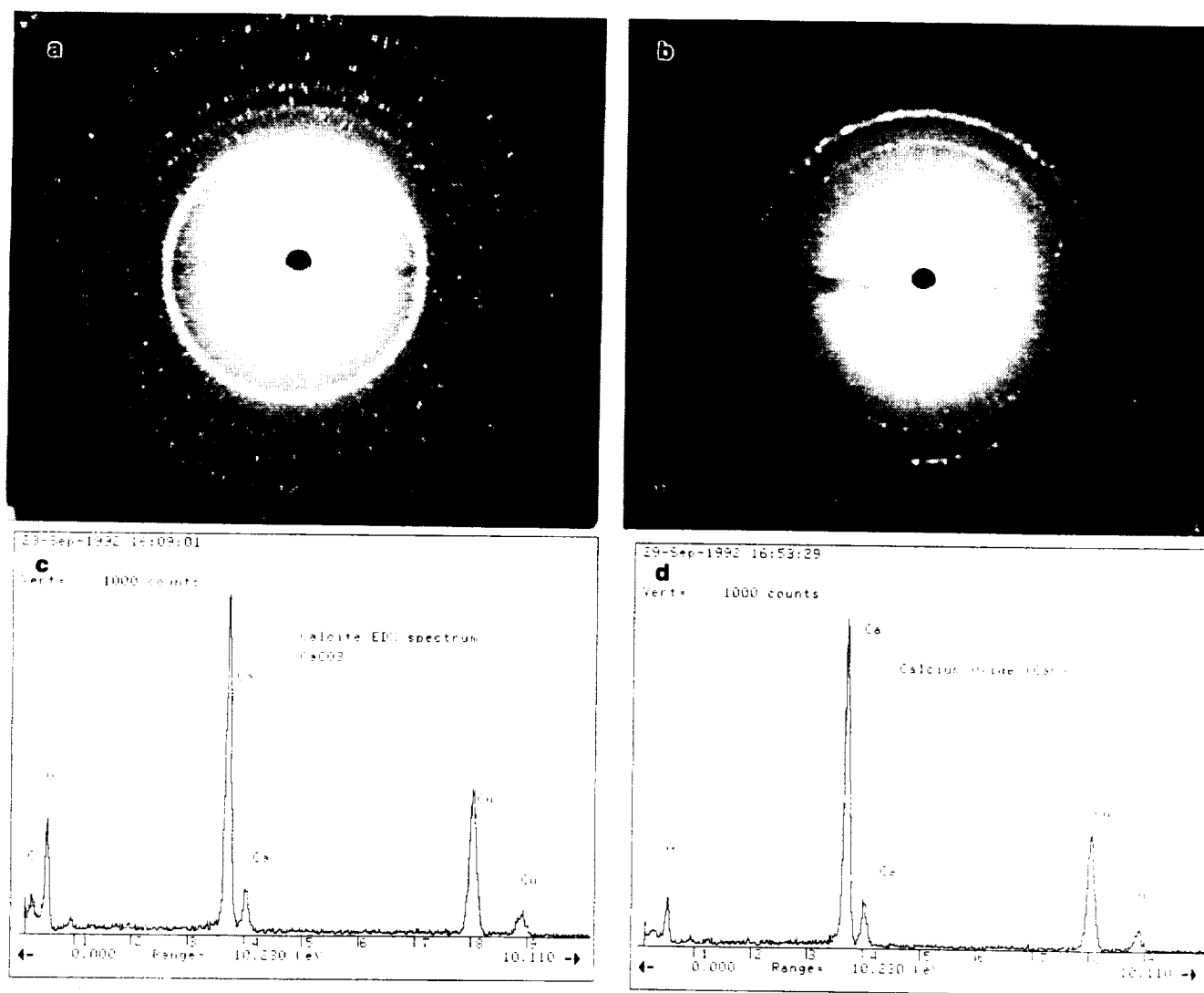


Figure 2. (a) X-ray diffraction pattern of calcite,  $\text{CaCO}_3$ . The original pattern was recorded on a piece of X-ray sensitive film slightly larger than a postage stamp. (b) X-ray diffraction pattern of calcium oxide,  $\text{CaO}$ . (c) Energy-dispersive X-ray analysis of calcite. (d) Energy-dispersive X-ray analysis of calcium oxide. The two minerals are difficult to distinguish from each other by their fluorescence spectra, but are readily identifiable through X-ray diffractometry.

**Significance of the results**

The XRD/XRF, once refined into a flight instrument, will be the only device capable of remote, *in situ* mineralogical identification of planetary surface material, windborne dust, rock fragments from drill cores, etc. A proposal for development of the instrument has been submitted to the Planetary Instrument Development Program (PIDP) jointly by Ames Research Center, Goddard Spaceflight Center, and Los Alamos National Laboratories. A mission concept proposal from Ames Research Center and Los Alamos National

Laboratories based on this instrument has been accepted for presentation at the Discovery Mission Workshop.

**Publications resulting from study**

Blake, D. F.; Bryson, C.; and Freund, F.: "Design of an X-ray Diffraction/X-ray Fluorescence Instrument for Planetary Applications," LPSC XXIII, 117-118, (1992).

**References:** None so far

# Radical Measurement by Zeeman Spectroscopy (RAMZES): A Prototype Instrument for Airborne *in situ* Measurements of Radical Molecular Species

## Investigator(s)

Thomas A. Blake, Charles Chackerian, Jr.,  
James R. Podolske, Ames Research Center,  
Moffett Field, CA 94035-1000

## Statement and importance of problem

The Radical Measurement by Zeeman Spectroscopy (RAMZES) Project is dedicated to developing a laboratory prototype of a flight instrument for the simultaneous detection of low level concentrations (mixing ratio of several parts per trillion) of paramagnetic molecules such as nitric oxide and nitrogen dioxide. These compounds, of course, play an important role in the catalytic destruction of stratospheric ozone. Central to understanding this destruction process is the ability to quantify and predict the amount of these highly reactive molecular species.

Current aircraft instruments are inadequate for detecting and quantifying these species because they (1) lack the necessary spatial/time resolution necessary to study small scale structures such as those encountered in plumes, (2) do not have the capability to detect simultaneously more than one molecular radical species (so as to put hard constraints on the theoretical models), and (3) rely on indirect schemes of detection which lead to ambiguities in the interpretation of the measurements. A collateral problem for our experiments is to quantify and minimize the perturbation on the ambient concentrations induced by the sampling flow system.

## Objectives of the study

The RAMZES project has three objectives. The first objective is to design and build mid-infrared and near-ultraviolet magnetic rotation, diode laser-based, spectrometers and to identify the limiting factors which determine detection sensitivity. These factors include magnetic field strength, sample pressure and temperature, modulation scheme and frequency, polarization efficiency, and shielding for electromagnetic interference.

The second objective is to determine the ultimate detection sensitivity, selectivity, linearity, and response time of the magnetic rotation technique

under stratospheric conditions. Molecules measured will be NO, NO<sub>2</sub>, and OH.

Our third objective is to assess the feasibility of building an aircraft-based, magnetic rotation spectrometer for *in situ* radical detection with diode lasers. Additionally, we will carry out a paper study on various sampling systems for an aircraft-based instrument considering potential cell wall losses for reactive radicals as a function of distance in the flow tube, flow tube diameter, Reynolds number, and wall material.

## Method

The ideal spectrometer for the proposed problem would (1) be sensitive to the low concentrations (pptv) of these radical species in the stratosphere, (2) have high spatial (forty meters on the ER-2) and high temporal (milliseconds) resolution, (3) discriminate between radical molecules and molecules such as H<sub>2</sub>O and CO<sub>2</sub> that would otherwise obscure the radical spectrum, and (4) observe spectra of several radicals simultaneously.

Instability in a laser's intensity amplitude is, typically, the largest source of noise in a standard direct absorption spectrometer. Even with the best modulation techniques, such a spectrometer would fall far short of the sensitivity required for stratospheric concentrations of some free radicals.

The spectroscopic method we have chosen for addressing the above mentioned experimental constraints is known as magnetic rotation spectroscopy (MRS). By reducing the effects of laser source noise, other investigators using infrared lasers have shown this technique to be superior to the direct absorption spectroscopy of free radical molecules by orders of magnitude in signal-to-noise ratio.

In magnetic rotation spectroscopy, linearly polarized light traverses an absorption cell along the cylindrical axis of a solenoid magnet whose field is modulated about zero field using a sinewave generator operating at about 1 kHz with an appropriate matching circuit. The solenoid, which contains the absorption cell, is placed between nearly crossed polarizers; the angle by which the polarizer axes differ from being perfectly crossed is denoted by  $\phi$ . As the laser frequency is tuned through a molecular resonance, the plane of

polarization of light is rotated at the magnetic field's modulation frequency. The rotation causes an intensity modulation behind the nearly crossed analyzer, which is detected by lock-in detection.

Linearly polarized light can be thought of as being composed of right and left circular components, and a paramagnetic molecule in the presence of a magnetic field will absorb either right or left circular light, depending upon the specific quantum selection rules of the transition. The dispersion associated with the absorption will create an anisotropy, or difference, between the way the right and left components of light will propagate through the cell. The anisotropy results in a net change in intensity and a rotation of the plane of polarization of the laser light emerging from the second polarizer (also called the analyzer). It can be shown mathematically that (despite the reduction of total light reaching the detector because of the nearly crossed polarizers) that portion of the detector signal which is attributed to laser noise is reduced by  $\phi^2$ , compared to a reduction by a factor of  $\phi$  in that portion of the detector signal which is attributed to a molecular transition. Thus the signal-to-noise ratio can be increased. This magnetic field-induced rotation does not occur for diamagnetic molecules, such as  $\text{H}_2\text{O}$  and  $\text{CO}_2$ , which in many spectral regions obscure the spectra of other, less abundant molecules such as free radicals.

### Progress and results

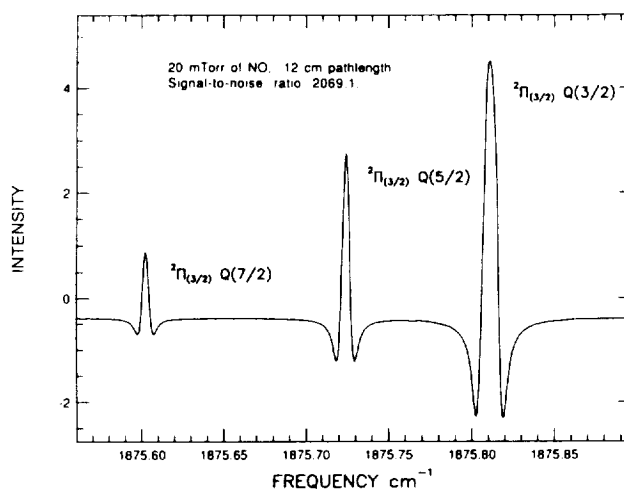
To date, we have achieved our first objective by designing and assembling in the laboratory a mid-infrared magnetic rotation spectrometer for detecting nitric oxide. We have also constructed a flow tube reactor for producing OH radicals and have taken magnetic rotation spectra of this radical using a ring dye laser. We are now working towards our second objective which is to quantify the limits of detection sensitivity. Money from the Ames Director's Discretionary Fund was used to construct these two spectrometers.

For detecting nitric oxide, the instrument's light source consists of a lead-salt, infrared diode laser that operates in the  $1875\text{ cm}^{-1}$  region ( $v = 1 \leftarrow 0$ ), its dewar, and control electronics. A monochromator is available for frequency calibration of the laser output. The spectrometer also includes alignment optics, a quarter wave plate, and polarizers.

Several solenoid designs were tested for their effectiveness in producing a 1 kHz, 200 Gauss, AC magnetic field. The present design uses a quarter-mile of 14-gauge magnet wire wound around a 1.5-inch-diameter, 10-inch-long piece of PVC pipe.

This solenoid, when driven by a 400 Watt AC power supply, can produce a 1 kHz, 600 Gauss AC magnetic field. An indium antimonide detector, preamp, and lock-in amplifier (referenced to the solenoid's modulation frequency) are used to detect and amplify the spectral signal. A Mac IIci that has data acquisition boards and LabVIEW software is used to acquire data from the lock-in amplifier.

Another important aspect of the spectrometer is its sensitivity. The figure below shows a magnetic rotation spectrum of the Q branch region of the nitric oxide fundamental band. The spectrum was obtained by placing the gas cell (20 mTorr of NO with a 12-cm path length) and solenoid between nearly crossed polarizers and scanning the diode laser slowly over the frequency range indicated. The signal was modulated by a 1 kHz, 100 Gauss, magnetic field, and detected by a lock-in amplifier. The measured signal-to-noise ratio for the  $^2\pi_{3/2}$  Q(3/2) transition is ca. 2000:1.



*Magnetic rotation spectrum of the nitric oxide fundamental band.*

On the basis of our preliminary results we estimate that we will be able to detect our target concentration of  $3 \times 10^8$  NO molecules/ $\text{cm}^3$ . To accomplish this we will incorporate a multiple reflection cell into the solenoid so as to increase the sample path length from the present 12 cm to 1000 cm. More efficient polarizers should further improve the instrument's sensitivity.

A magnetic rotation spectrometer for detecting hydroxyl radical has been constructed at Stanford University. This spectrometer uses a frequency doubled ring dye laser to access the  $A^2\Sigma \leftarrow X^2\Pi$  OH transition at 308 nm. The radical is produced by reacting a 1%  $\text{NO}_2$  in helium mixture and hydrogen

atoms in a glass flow tube. The hydrogen atoms are produced by flowing a 1% H<sub>2</sub> in helium mixture through a microwave discharge. The total pressure in the flow tube is approximately 5 Torr. Spectra of the R-branch region were obtained and a Voigt

profiles were fitted to individual transitions; this data gave a temperature of 295 K, and a number density of  $\sim 5 \times 10^{12}$  OH radicals/cm<sup>3</sup>. Zeeman and magnetic rotation spectra were also obtained using a 3 kGauss DC magnet.



# Plasma Spraying of Nonoxide Ceramic Coatings Using a Constricted Arc Jet

## Investigator(s)

Jeffrey Bull and Paul Kolodziej, Ames Research Center, Moffett Field, CA 94035-1000

## Other personnel involved

Ernie Fretter, Greg Tice, Jim Magyary, Aerotherm Corp., Mountain View, CA

## Objectives of the study

Future manned space vehicles and planetary probes will require thermal protection system materials with much higher performance than the SiC coated carbon/carbon (RCC) used on the Space Shuttle Orbiter's leading edges and nose cap. Recent arc-jet tests on SiC reinforced diborides of zirconium ( $ZrB_2$ ) and hafnium ( $HfB_2$ ) have shown that they are capable of surviving heat fluxes two to three times greater than RCC. These materials are enabling technology for vehicles like NASP which require small radius leading edges to minimize aerodynamic drag.

Presently diboride composites are formed by uniaxially hot pressing the appropriate mixture of powders to form rectangular or circular billets which must be subsequently machined to shape. The hot pressing and machining of these hard refractory materials is very expensive.

The plasma spray process is an alternative means of fabricating discontinuous diboride composites for use as thermal protection materials. Among its many potential advantages is the capability to manufacture complex shapes without costly machining. The objective of this study is to demonstrate that  $ZrB_2$  can be plasma sprayed using a constricted arc-jet.

Conventional plasma spraying of oxide ceramic coatings is typically done in air. Nonoxide ceramics are deposited via vacuum plasma spraying (VPS). In both cases the spray gun is a fluidized bed feeder attached to a simple plasma arc chamber, which melts and accelerates the powder through a nozzle to form a layered coating. Thermal barrier coatings are applied in this manner to enhance the performance of metal components in high-temperature abrasive environments such as those that exist in turbine engines. Attempts at spraying  $ZrB_2$  by conventional means resulted in uniformly thick (30-mil) coatings; however, the physical properties were not equal to those of the hot pressed  $ZrB_2$ . Apparently the plasma spray process oxidized the  $ZrB_2$  powder during deposition, and

the coating was very porous. To reduce oxidation, the  $ZrB_2$  powder can be sprayed within a vacuum chamber using argon. Vacuum plasma spraying is a state of the art technology, and VPS units are not readily available for producing diboride coatings.

An alternative technology, the constricted arc-jet, was developed for creating a high enthalpy plasma stream for long duration testing of heatshield materials. In order to achieve a high enthalpy plasma stream, these arc-jets constrict the gas to flow within a tube containing an electrical arc. Powder injected into the constrictor tube is also forced into the plasma and rapidly heated along with the gas stream. Because rarified flow effects reduce the heat transfer to the small powder grains at low pressure, a VPS would have difficulty melting ceramic powders in argon. The long residence time of the constrictor tube overcomes this problem as well as increasing the throughput.

## Progress and results

Two powder injection ports were plumbed into the constrictor tube of the Aerotherm 5-MW arc-jet facility (fig. 1). Long powder residence times in the constrictor were achieved by attaching the fluidized bed feeder to the upstream port.

Plasma sprayed coatings were deposited on substrates located 6.5 inches downstream of the nozzle exit on a water cooled sting. A typical run lasted for about 3 minutes and consisted of three phases; constrictor startup, followed by calibration of the argon stream to set consistent operating conditions, and then injection of the powder to begin coating.

$ZrB_2$  powder was injected into the constrictor tube at two locations. Most of the powder exited from the nozzle as a vapor when injection was done at the upstream port and no deposit was observed on the substrate. Thin coatings were observed visually and by optical microscopy on molybdenum tags which were placed on the sting arm during the runs. Thicker coatings were deposited on the water cooled copper model holder. Although these locations were separate from the actual substrate location, they were nonetheless representative of deposits formed from constricted arc plasma spraying. X-ray diffraction analysis of coating samples taken from the sting show a diffraction pattern consistent with that identified for  $ZrB_2$ . On the other hand, most of the powder exited from the nozzle as a solid when injection was done at the downstream port. The solid particles exited the

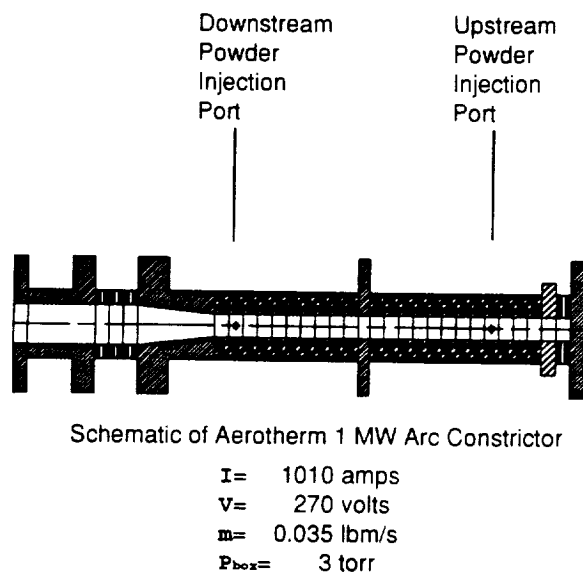
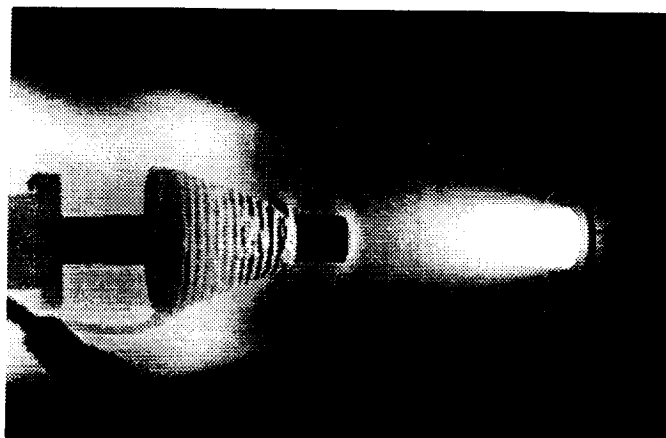


Figure 1. Experimental arrangement for constricted arc plasma spraying of nonoxide ceramic powder.

nozzle at high velocity to completely erode a graphite holder and sandblast the sting clean.

### Significance of the results

Coating deposition from the gas phase is inefficient because large amounts of the raw material end up depositing on the inside of the vacuum chamber and not on the substrate. Our results indicate that the location of the powder injection port is a primary variable in determining the particulate residence time in the constrictor tube and whether it exits the nozzle as a solid, liquid or gas (the liquid phase is desired). By moving the injection port downstream, the powder has a shorter residence time and is not heated to vaporization. An optimal location, to fully melt the powder without vaporization and increase coating efficiency, can be found by further investigation.

Other parameters influence the efficiency and quality of the coating deposition. By lowering the pressure in the vacuum chamber, supersonic flow can be achieved in the nozzle exit flow. Under supersonic conditions, impact velocities with the substrate are higher and lead to the formation of more uniform and

dense coatings. Stable constricted arc-jet operation with supersonic nozzle flow is common practice. Due to the limited time constraints of this study, a supersonic flow investigation was not accomplished.

Conventional plasma spraying is a challenging process technology to control with sufficient precision for reliable production of high quality coatings. Advanced plasma spray guns are under development for better process control and higher production rates. The constrictor tube has good potential for advancing the state of plasma spray gun design, particularly for ceramic powders like the diborides that require high heating rates under inert environments. Current VPS systems are not capable of melting powders like  $\text{ZrB}_2$  at the low argon pressures demonstrated in this study. Final negotiations are under way with Sandia National Laboratory to borrow a 5-MW constricted arc-jet for further development of constricted arc-jet plasma spraying.

**Publications resulting from study:** None so far

**References:** None so far

# MIR Study of Disks Around Young Stellar Objects

## Investigator(s)

Harold M. Butner and Fred Witteborn,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

Disks around young stars may be future sites of planet formation. Understanding the physical character of such disks is important if we wish to test theories of star formation and planet formation. Mid-infrared emission from disks offers an opportunity to study disk properties on size scales of 10-40 AU (1 AU =  $1.5 \times 10^{13}$  cm), similar to our own solar system. However, proper interpretation of mid-infrared data involves use of detailed radiative transfer models. Effects such as backwarming by a surrounding spherical dust shell (or envelope) have been ignored in previous work. The objective of this study is to develop improved radiative transfer models for young stellar systems (stars + disks + envelopes) and to apply these models to a sample of nearby young stars.

## Progress and results

As a first step, we constructed an improved disk model to allow us to handle a variety of possible physical conditions. For example, we can vary the disk size, radial distribution of material, dust optical properties, and the possible effects of backwarming from a spherical dust shell. In figure 1, we illustrate how the presence of an envelope warming the disk can dramatically alter the predicted spectral energy distribution (SED) of the disk. In addition, an envelope will absorb some of the disk's emission. We have integrated our models to allow us to estimate the final source spectra.

We applied our dust code to the case of L1551-IRS 5. This source is a one-solar-mass young stellar object located in a nearby molecular cloud. Deeply embedded in the cloud, the central object is invisible at visual wavelengths. Through use of our models, we showed that L1551-IRS 5 probably has a disk of about 50 AU radius surrounding it. We also were able to place fairly tight limits on the disk properties. In particular, we were able to demonstrate that emission from the envelope back onto the disk warms the disk enough to significantly alter the total energy distribution of the source. The final source model for L1551 is in good

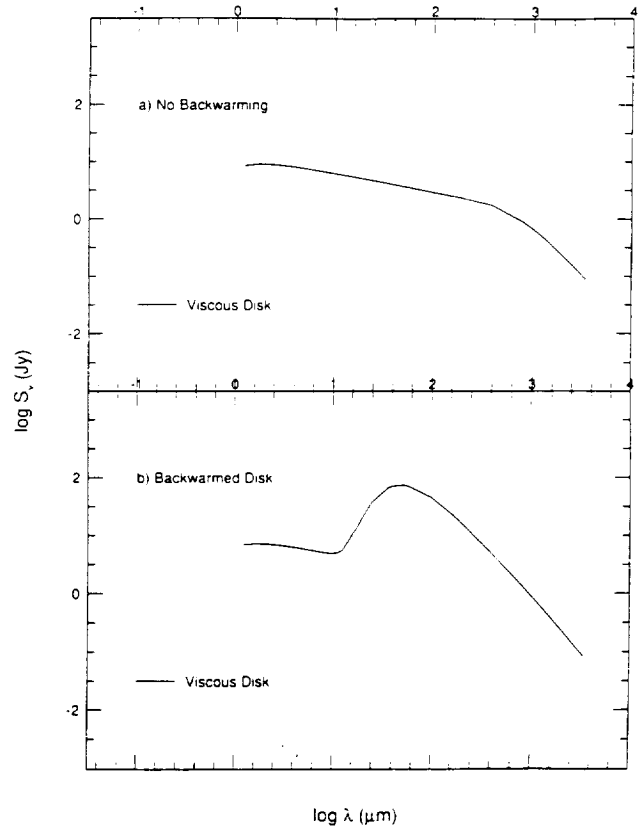


Figure 1. Effect of backwarming. (a) Intrinsic disk spectrum of a viscous accretion disk where the disk has both viscous accretion of material (so the disk is self-luminous) and reprocessing of the central star's radiation. (b) Intrinsic disk spectrum where the disk has been warmed by an external radiation field (backwarming) in addition to the processes in (a).

agreement with the predictions of star formation models.

We are currently improving our models by adding additional physical parameters to allow us greater flexibility when modeling. For example, we are including a scattering term in the disk calculations.

In addition, we used the Ames HIFOGS system with the Mount Lemmon 1.5m telescope to obtain mid-infrared spectra between 8 and 13 microns for half a dozen nearby young stellar objects. These objects were chosen because they have evidence of disks from previous studies at millimeter wavelengths. Our

observations have much higher spectral resolution (factor of 4) than any previous mid-infrared observations of these objects. We are currently reducing the observations.

### **Significance of the results**

While our study is only partially completed, we have demonstrated that our techniques allow us to model young stellar systems more successfully than before. Backwarming of a disk can significantly alter which source model best fits the observations. The possibility exists that similar effects can be seen in visible young stellar systems like the T Tauri stars. These solar mass young stars are the best examples we have for the proto-solar environment. Our models should allow us to estimate the temperatures and densities to be found in the circumstellar material around these stars.

### **Publications resulting from study**

Poster given at Center for Star Formation Workshop, Berkeley, CA, August 1992.

Article on L1551-IRS submitted to *Astrophysical Journal*, August 1992.

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# Origin of Life: Exploration of the Water/Air Interface as a Reaction Zone

## Investigator(s)

Sherwood Chang, Ames Research Center,  
Moffett Field, CA 94035-1000  
Anastassia Kanavarioti, University of California,  
Santa Cruz, CA 95064

## Other personnel involved

Michael Stronach, University of California,  
Santa Cruz, CA 95064

## Objectives of the study

Current views on the origin of life suggest that many compounds of prebiological importance may have been difficult to synthesize in conventional laboratory simulations of environmental conditions on the early Earth. To account for the abundance of organic compounds required for the origin of life, several environmental processes have been suggested including atmospheric photochemistry and electrical discharges, thermal reactions in tidepools and submarine hydrothermal systems, and impacts of comets and asteroids. One major geophysically active environment that has not been considered is the water/air interface. Water/air interfaces are ubiquitous on Earth, occurring primarily as bubbles at the sea surface, in thermal springs and marine hydrothermal systems and in cloud droplets (ref. 1). At any one time, about 4% of the surface of the ocean is covered with bubbles, and the amount of actual water/air surface represented by these bubbles is enormous. W. H. Carothers (ref. 2) proposed in 1936 that complex molecules might be synthesized at interfaces where molecular configurations could have preferred (rather than random) orientations. Specific molecular orientation effects are critical to the function of enzymes and other catalysts. Work by Eisenthal and coworkers (ref. 3) has shown that water molecules located at the water/air interface are oriented with the hydrogen atoms immersed in the liquid and the oxygen atom pointed into the air. Membrane forming molecules also have preferred orientations. These and other investigations of water surfaces suggest that concentration and orientation effects that occur at interfaces may significantly alter the rate and course of a chemical reaction (ref. 4). The objective of this study was to determine the influence of water/air interfaces on the course of well-studied model reactions of prebiological relevance.

## Methodology

One reaction chosen for study is the phosphorylation of guanosine in the presence of cyanamide under pH-buffered conditions. Expected products are phosphate esters of guanosine. A second reaction was the hydrolysis of diguanosine 5',5'-pyrophosphate to guanosine 5'-monophosphate. Typically, the procedure involved bubbling air through fritted discs into 100-200 ml reactant solutions held in 1-l volumetric cylinders. A small amount of surfactant, tetrabutylammonium dihydrogen phosphate (TBAP) is added to the reaction mixture in order to increase bubble formation. The water that slowly evaporates during bubbling is replenished periodically. Control samples are held at room temperature in a small vial for comparative purposes. Small samples of the reactant solution are withdrawn at various times and held at -40°C for future analysis. Samples of reactant solutions are analyzed with reverse-phase high performance liquid chromatography (HPLC) on a Hewlett-Packard HP 1090 instrument fitted with a C18 column. UV spectra of eluting compounds are obtained directly by means of a diode array detector fitted to the HPLC.

## Progress and results

Vigorous bubbling of air through aqueous solutions causes the slow disappearance of reactants by aerosol formation. The timescale of such removal is of the order of days depending on the gas throughput. A mass discrimination effect occurs during this loss so that low molecular weight reactants are depleted faster than those of higher molecular weight. Consequently, a reaction occurring during bubbling may cease after a day because an essential low molecular weight reactant has disappeared. Under these conditions measurement of rates of reactions was not possible.

Both the phosphorylation and hydrolysis reactions yielded erratic results. That is, product formation in excess of control experiments was observed on several occasions, but the results could not be routinely reproduced. For the phosphorylation reaction, guanosine monophosphates were observed to form at room temperature whereas reports in the literature indicate that higher temperatures were required. Hydrolysis of the diguanosine 5',5'-pyrophosphate to guanosine 5'-monophosphate also occurred despite the fact that under normal solution conditions the reaction is immeasurably slow at room temperature. A variety of

other reactions were studied as well, but none yielded notable results.

#### **Significance of results and future work**

The cause(s) of the erratic results remain(s) unclear. Therefore, the enhanced reactivities observed in two model reactions may not be reliably attributed to effects associated with a greatly increased water/air interface environment. Conceivably, reactions could have occurred in the aerosol phase. Hydrolysis products were observed under circumstances where products of the aerosol phase condensed on the walls of the cylinder. It is noteworthy, however, that on the sea surface, bubble bursting is thought to be the cause of ejection of aerosol particles into the atmosphere. In order to resolve the ambiguities and obtain consistent results, a different experimental approach will be required which allows control of bubble size, the capture and analysis of aerosols, and the connection of several reaction chambers in series. The last feature

would provide a means of assessing the effect of multiple cycles of aerosol formation in a closer simulation of sea surface processes.

**Publications resulting from study:** None so far

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# Human Exploration Demonstration Project

## Investigator(s)

Edward Chevers and David Korsmeyer,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

The Human Exploration Demonstration Project (HEDP) is a multi-division task that addresses the advanced technology requirements necessary to implement an integrated working and living environment for a planetary surface habitat. The HEDP project began in the fall of 1991 and will continue to the summer of 1994. The integrated environment will consist of life support systems, physiological and psychological monitoring of the flight crew, a virtual environment workstation, and centralized data acquisition and habitat systems health monitoring. Several robotic systems external to the habitat will perform activities to provide representative workloads for the human subjects.

Four basic goals for the HEDP have been established.

1. Provide a simulator for evaluation of technology in an integrated system setting.
2. Create a realistic environment for introduction of new technology.
3. Enhance the technology development and evaluation process through synergistic cooperation of multiple Ames divisions.
4. Identify promising technology concepts to programmatic Centers for new and existing NASA projects.

## Scope

The HEDP consists of a working environment that is contained in a living environment. The living environment will be housed in the Controlled Environment Research Chamber (CERC), and the working environment will be remotely operated to the simu-

lated planetary landscape. The two environments are coupled through an underlying data network that includes a common set of services and provides a medium for overall system integration. Many of these services utilize artificial intelligence technologies to maximize autonomy and minimize crew workloads. The living environment has both life support and life monitoring subsystems. The working environment includes standard and virtual reality workstations. External to the habitat will be robotic devices used as crew workloads and targets for workstation commands. These devices will not be used for the development of robots per se but to create realistic operational scenarios equivalent to those anticipated on the lunar surface and to develop the robotic controls systems and technologies required.

## Progress and results

As of December 1992, the HEDP has finished phase I of the project and is into phase II. This second phase focuses on the implementation and initial integration of the project's component technologies. Phase III, the physical installation of the final testbed, will begin in October of 1993. Phase IV, the system integration and checkout phase, will begin in January of 1994. The demonstration phase of the project will begin in April of 1994.

## Publications resulting from study

- Clearwater, Y. A.: NASA Lunar Surface Habitat and Remote Exploration Demonstration Project. SAE Paper 921194, SAE 22nd International Conference on Environmental Systems, Seattle, WA, July 13-16, 1992.
- Chevers, E. S.; and Korsmeyer, D. J.: The Development of the Human Exploration Demonstration Project (HEDP), A Planetary Systems Testbed. AIAA Paper 93-0558, AIAA 31st Aerospace Sciences Meeting, Reno, NV, January 11-14, 1993.

**References:** None so far

# Development of Fiber-Optic Acoustic Sensors for Wind Tunnel Applications

## Investigator(s)

Y. C. Cho (P.I.) and P. T. Soderman,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

M. G. Irizarry, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

Acoustic measurements in wind tunnels are subject to certain interference noise effects which are not found in anechoic chambers. Such effects include wind noise, flow-sensor interaction noise, flow induced sensor vibration, deflection of acoustic waves by sensor induced boundary layers, reflections from sensor support components, and noise due to temperature fluctuation. Currently existing acoustic sensor techniques are not adequate to deal with these problems. The objective of this study is to develop new advanced acoustic sensors to eliminate or minimize these interference restrictions.

Fiber-optic interferometric sensor technology, which has almost matured in underwater acoustics, is adapted here to develop new sensor techniques for aero-acoustic measurements but with new sensor head designs. This technology utilizes the property that the light wave propagating through optical fiber undergoes phase modulation when the fiber is exposed to external fields. The phase modulation is then interferometrically retrieved and processed to determine the external fields. This technology offers a number of advantages such as high sensitivity, wide dynamic range, compact sensor package, lightweight, geometric versatility, superb telemetry capability, high temperature tolerance, and immunity to electromagnetic interferences.

## Progress and results

NASA's first fiber-optic microphone was developed and fabricated in a breadboard form. Unlike in underwater acoustics applications, no acoustically compliant mandrel was used. Instead, polymeric jackets were used as fiber coatings to enhance the acoustic sensitivity. Preliminary tests of this sensor were performed in an anechoic chamber. The test results show that (1) the acoustic sensitivity exceeds an estimation by 60 dB, (2) the noise floor is in the range of -4 dB to 10 dB in reference to 20 $\mu$  Pa, which is far below the values required for wind tunnel tests, and (3) the frequency response function is stable but requires further efforts, including more elaborate tests and improved sensor head designs.

## Significance of the results

The fiber-optic interferometric sensor was developed and tested for the first time for aeroacoustic measurements. The test results demonstrated successfully its feasibility as an aeroacoustic sensor. With the advantages mentioned earlier, the results show the enhanced potential of this sensor technique as a powerful instrument to solve complex acoustic measurement problems in wind tunnels which cannot be overcome with the conventional transducer techniques. Furthermore, this technology can easily be applied to studies of pressure fluctuation associated with high speed research and parametric studies of transition as well as other acoustics related research.

## Publications resulting from study

Cho, Y. C.: Fiber-optic interferometric sensors for wind tunnel applications, SPIE Paper 1795-04, 1992.

**References:** None so far



# Propulsion Instrumentation Research Chamber

## Investigator(s)

Timothy R. Conners, L. Dean Webb,  
Sheryll A. Powers, and Ronald J. Ray,  
Ames-Dryden Flight Research Facility,  
Edwards, CA 93523-0273

## Objectives of the study

The major objective of our DDF task was to develop a low cost facility for testing instrumentation designed for propulsion systems. There are many types of instrumentation designs in development that promise a revolution in engine diagnostics and control, particularly non-intrusive sensors. The Propulsion Instrumentation Research Chamber (PIRC) was created to accelerate the transition of these new systems from development to the flight environment. The PIRC, designed to fit between a bellmouth and F100 turbofan engine on a ground test stand, provides a low cost facility for inlet and engine face testing. It will accommodate different types of instrumentation while subjecting the sensors to the real world environment of an operating engine. Hands-on experience with new instrumentation can be gained at a low cost per test.

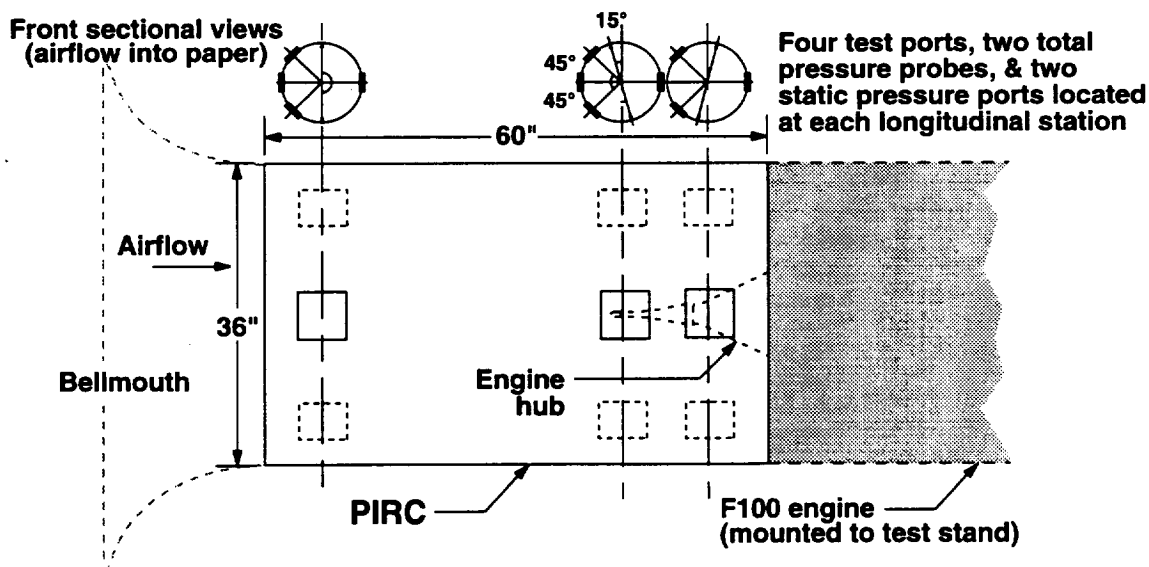
## Progress and results

Requirements and preliminary design for the PIRC, shown below in side view, were completed in January

1991. The system design was balanced to provide a suitable test facility for various types of instrumentation while keeping construction costs low. Final design of the chamber was sub-tasked to PRC, Inc. King Welding (Camarillo, Calif.) manufactured the PIRC and it was delivered on January 9, 1992.

The Propulsion and Performance branch at Dryden successfully advocated the phase II funding of Aerometrics, Inc., Mountain View, California, for their work in developing a flight-worthy laser velocimeter for inlet flow studies. The PIRC will play a major role in the development of this sensor and should significantly accelerate its transition into a research aircraft. It appears that Aerometrics will be our first customer. A phase I SBIR award has recently been awarded to Physical Sciences, Inc., for a non-intrusive mass flow sensor for flight applications. Although the phase I program will not produce hardware that we could test with the PIRC, the phase II effort, if awarded and as proposed, would almost certainly use the chamber.

A significant problem occurred late last year that has affected our ability to use the PIRC in the near term. We had targeted a non-flight-worthy F100 engine at Dryden to use at the engine test stand with the chamber. Unfortunately, the engine was marked as expendable without our knowledge, and was sent to China Lake for destructive testing. In the spring-summer time frame of next year, Dryden's HIDE C F-15 aircraft will be decommissioned along with its



*Side view of propulsion instrumentation research chamber.*

F100 derivative turbofan engines. We are hopeful that we will have access to these engines for use with the planned Aerometrics tests. Fortunately, this fits well into Aerometrics' schedule because it is unlikely that they will have hardware available for ground testing before then.

Presently we are working closely with Pratt & Whitney to formulate the best method for transporting the chamber to their ground test facility here at Edwards. We hope to work out any logistics problems before we begin the first series of tests.

The DDF funding that remains will be used to procure an air data instrumentation suite for the chamber. We will work closely with Aerometrics in this area so that we have a traditional air data system that will complement their laser velocimeter sensor. Remaining funds will be used for fuel and support

personnel costs for the actual tests at the Pratt & Whitney test stand. These costs should be reduced because of an on-going support contract that Dryden has with Pratt & Whitney.

Our DDF objectives were met this past year with the completion and delivery of the PIRC and the securing of Aerometrics as our first customer. We plan on delaying our final report until the end of FY93 so that we can include data from future Aerometrics sensor system testing.

**Significance of the results:** None so far

**Publications resulting from study:** None so far

**References:** None so far

# A Prototype Infrared Gas Analyzer for Characterizing Plant Growth during Space Flight

## Investigator(s)

James Connolly, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Raman Sargis, Sverdrup Technology,  
Ames Research Center,  
Moffett Field, CA 94035-1000  
David Bubenheim, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

Accurate and reliable measurement of CO<sub>2</sub> and water vapor is critical for characterization of photosynthesis and transpiration of green plants in space. All food production, air revitalization, and water purification functions of plants depend on proper function of photosynthesis and transpiration. Current CO<sub>2</sub> analysis technologies used in ground-based laboratories have several characteristics which would severely restrict and limit their reliable and safe use in space flight. The analyzer design proposed here would utilize alternative component technologies and operation approaches to address each of the limitations and safety problems present in current instrumentation.

Typical portable CO<sub>2</sub> gas analyzers operate based on the infrared radiation absorption of CO<sub>2</sub> gas. As the gas concentration inside the "gas cell" increases, the amount of radiation from the source reaching the sensor diminishes. The measured radiation power is then normalized against a pre-determined peak radiation to produce a measurement of the CO<sub>2</sub> gas concentration. The infrared gas analysis method is advantageous over other methods, especially in space, because it does not require use of chemicals to measure gas concentrations as most alternate methods do. However the use of existing infrared gas analysis instruments for high accuracy CO<sub>2</sub> measurements over long periods of time requires regular calibrations, typically daily, and consideration of environmental conditions surrounding the analyzer.

## Progress and results

The gas analyzer components requiring improvements were divided into two groups. Within these groups potential solutions were investigated.

## A. Alternative Radiation Sources under Investigation to Improve the Infrared Radiation Characteristics

1. **Infrared Laser:** The laser beam's energy density is concentrated within a narrow bandwidth, at about 1.2  $\mu\text{m}$ , where CO<sub>2</sub> gas absorption lines exist. The wave length of the laser may be tuned to that of a singular gas absorption line. This scheme may also be used to calibrate the instrument.

The characteristics of a miniature infrared laser were studied using computer simulation. Results of the study showed that (using the current technology) it would take a 50-meter laser beam path length to measure CO<sub>2</sub> concentrations with less than one part per million (ppm) resolution at 500 ppm gas concentration.

2. **Gas-Filled Flash Bulb:** Unlike the laser, a flash bulb is a wide band radiation source. The infrared radiation of the flashbulb was studied using a breadboard gas analyzer which was constructed to allow study of various radiation sources. The infrared radiation of the flashbulb was highly detectable and followed the expected mathematical model.

## B. Radiation Measurement and Analysis

Infrared radiation sensors are inherently sensitive to fluctuations in temperature. Therefore it is critical that the temperature of the sensor is monitored and actively controlled. The infrared sensor element used is mounted on a thermo-electrically cooled (TEC) plate. The temperature of the sensor was monitored using a thermistor which was attached to the TEC plate. The results indicated a stable sensor temperature at -30°C which allowed for low sensor thermal noise.

Studies in the area of Digital Signal Processing (DSP) were conducted which indicated that DSP methods may be used to improve gas concentration measurement.

## Significance of the results

The efforts of the past year resulted in the identification of various subsystems and the design and construction of a breadboard CO<sub>2</sub> analyzer unit to allow experimentation with different components and analyzer configurations. Feasibility studies indicated that a miniature infrared laser as well as a special type of high energy flash bulb may be used as alternate infrared radiation sources in CO<sub>2</sub> gas analyzers.

Successful implementation of either of the alternate infrared radiation sources will eliminate the use of traditional mechanical choppers or beam splitters. The characteristics and performance of the infrared radiation sensing subsystem, currently designed, will meet design requirements. DSP methods may also allow simultaneous multiple gas concentration measurements. During the second year of the project, the existing miniature laser and flashbulb will be modified and tailored for use in CO<sub>2</sub> analyzers. Also data

analysis techniques will be developed to improve gas concentration measurement techniques. At the conclusion of the second year, a set of design guidelines will be developed to allow the design and integration of CO<sub>2</sub> analyzers within existing U.S. and Russian space study plant growth systems.

**Publications resulting from study:** None so far

**References:** None so far

# Improving Photometric Extrasolar Planetary Detection

## Investigator(s)

Laurance Doyle and Kent Cullers,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

The detection of extrasolar planetary systems is of vital importance to (1) our understanding the place our planet has in the cosmos and the origin of our solar system (including whether it is unique), and (2) our accurately estimating the number of possible likely targets for the NASA Search for Extraterrestrial Intelligence (SETI). However, detecting extrasolar planetary systems is one of the most difficult observational problems in astronomy today, and each method has its difficulties. The photometric method, which measures a drop in the brightness of the star due to the transit of a planetary body in the line-of-sight, is the **most sensitive detection method**. However, it clearly relies on the planetary orbital plane being seen edge-on by the observer. The photometric method can detect a drop in the brightness of a star 1% for a Jupiter-sized planet and 0.1% for an Earth-sized planet) due to the transit of a planet in the line of sight (two-color photometry removes ambiguities due to stellar variability, starspots, or limb darkening). Although this method is the most sensitive (medium-sized, 30-inch telescopes can be used), it relies on the planetary orbital plane being in the observer's line of sight. This is because the orbital plane of the planetary system has to be less than  $2^\circ$  from the line of sight of the observer to obtain a measurable planetary transit. This means that, for a random distribution of planetary orbital plane inclinations, over 1000 stars would have to be monitored for over a year to obtain one detection. This method is unique, therefore, in that with present technology it is not detection limited, but **probability** limited. This study will improve that probability in two ways. (1) We will pre-constrain the likely single star planetary orbital planes by compiling a catalogue of stellar rotation axes inclinations to the line of sight which, in turn, will give the expected planetary orbital plane for single systems. We can then designate, ahead of time, which systems are close enough to being edge-on so that the photometric detection method may be used. (2) We will monitor

eclipsing binary stars—which have expected planetary orbital planes that are already edge-on, have two stars with which to confirm a planetary transit, and have stable planetary orbital regions which have been shown to exist for most configurations of such close systems—for evidence of such extrasolar planetary systems. This will be the effort of the second year of funding.

## Progress and results

In the first year for this study we have already determined the rotation axis inclination from the line of sight for over 200 stars using stellar rotation periods (determined from the CaII H&K emission line spectra, in the case of late-type stars and from variations in the magnetic field spectral lines, in the case of early-type stars). We expect to submit this new stellar parameter catalogue for publication before the end 1992. In the process of compiling this catalogue, we have also discovered a number of astrophysically interesting relationships between younger and older stars, including indications that T Tauri stars (pre-main sequence stars) have the same velocity distribution as stars already on the main sequence. This result is significant in further revealing the actual angular momentum processes that stars undergo during the planet forming stage. (This result will be submitted for publication in the refereed literature.)

## Significance of the results

We are applying the above findings to provide improved detection statistics for the photometric method—specifying a list of nearly edge-on systems to be monitored (present accuracy is limited to about  $\pm 8^\circ$  at  $i \approx 90^\circ$ ). This constraint would narrow the possible number of stars in a sample that could be successfully monitored for photometric detection of extrasolar planets to about 1/7 the previous "random" sampling. Selection of infrared excess stars might further constrain this selection. In addition, however, this determination of expected extrasolar planetary orbital planes can be very useful (and in some cases essential) for the other detection methods as well.

For example, a specification of the planetary orbital plane could remove proper motion and parallax vectors—large secondary effects—from the expected astrometric wobble of a star caused by a planetary

system. Pole-on systems could also be specified for direct imaging efforts as well as preferred candidates for astrometric measurements (accuracies of  $\pm 0.5$  can be achieved at  $i \approx 0^\circ$ ). One could also directly compute masses of stellar companions obtained using the radial velocity method—some present measurements already showing very promising results if the system's inclination can be calculated.

The photometric method for detecting extrasolar planets benefits the most from this study and becomes a very viable method, using existing modest equipment, when the probabilities of detection can be improved. We have outlined two major contributions to this improvement. One is to pre-determine the expected planetary orbital plane using asymmetries in stellar atmospheres to derive the stellar rotation axes inclinations, and the second is to extend photometric observations of eclipsing binary stars where the extrasolar planetary orbital plane is already expected to be

edge-on. Both results bring the observing tasks required to detect extrasolar planetary systems to a manageable level for a collaboration of this size. The results also begin to constrain the probabilities well enough so that, in case of non-detections, significant knowledge about extrasolar planets existing around some single stars (as well as short-period double stars) may be gained.

#### **Publications resulting from study**

As stated above, we are planning to publish the first Catalogue of Stellar Rotation Axes Inclinations in 1992 for the benefit and application of the extrasolar planetary detection community. We will be applying these results in the second half of this Director's Discretionary Fund research using the photometric method to detect extrasolar planetary systems around nearby single and eclipsing binary stars.

# A Resonant Ge:Ga Far Infrared Photoconductor

## Investigator

Jam Farhoomand, Orion TechnoScience,  
Palo Alto, CA  
Robert E. McMurray, Jr., Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Bill Knowlton, Kohei Itoh, Eugene E. Haller,  
Lawrence Berkeley Laboratory,  
Berkeley, CA 94020

## Objectives of the study

The future projects for space-based observatories, such as the Space Infrared Telescope Facility (SIRTF) and the Large Deployable Reflector (LDR), have introduced new challenges to the development of far infrared detectors. One of the primary objectives of these projects is to make astronomical observations under low-background conditions over a broad spectral window. In order to fully realize this scientific objective, the requirements on detectors, in terms of responsivity and noise equivalent power (NEP), have necessarily become more stringent.

In the far infrared, the most successful and promising detectors are extrinsic photoconductors, such as gallium doped germanium (Ge:Ga). Several parameters play a fundamental role in the detection process. With the understanding that these parameters are interrelated, and that there is an inevitable compromise in optimizing one parameter at the expense of the others, one desires unity quantum efficiency, high responsivity, low NEP, and immunity against undesirable effects of gamma rays.

The quantum efficiency, which is perhaps the single most important parameter of a photoconductor, is enhanced by increasing the optical or absorption depth of the detector element. A longer optical depth can be achieved by geometrical means and/or by increasing the dopant concentration. Both of these approaches can have serious drawbacks, especially for low-background astronomy. Increasing the dopant concentration will improve the absorption coefficient but, at the same time, will increase the leakage current.

## Progress and Results

Significant progress has been made toward the objective of producing a photoconductive detector with unit quantum efficiency. The main steps, which were required in order to realize the final goal, were as follows. First, all of the appropriate calculations were made to determine the proper conditions to achieve unit quantum efficiency. Next, the experimental verification required production of slices of Ge:Ga each with a thickness of the order of 50 $\mu$ m and a flatness of a few microns over an entire one-inch-diameter wafer. A study was required of the surface reflectivities of Ge, ion implanted contacts in Ge, and gold reflective layers on Ge. Proper choices of the Ge:Ga doping, ion implant characteristics, and gold thickness were made in order to achieve the final detector. Finally, all of these choices must be implemented in production of the final detector. After all of this is achieved, the detector must be tested in an infrared spectrometer to verify that the unit quantum efficiency condition exists. If any of the specifications were not properly incorporated, iterations of the detector production must be made in order to achieve the correct final detector.

The task of producing optically polished Ge samples of the proper thickness was contracted in an inter-agency agreement to the Ge detector group at Lawrence Berkeley Laboratory under the direction of Prof. Eugene Haller. His students were able to produce nominally 50 $\mu$ m-thick Ge wafers from one-inch-diameter single crystal slices, which had the required optical flatness for use as a Fabry-Perot cavity in a resonant detector. This task was achieved initially using low-doped Ge, which was more easily available, in order to optimize the polishing procedures. These low-doped slices were tested by us at Ames using our far infrared spectrometer. Both thickness and flatness were mapped out over the surfaces of the wafers. Eventually, acceptable polishing and mounting techniques were established which enabled the production of acceptable wafers for this detector effort. A final set of wafers of proper Ga doping for far infrared detection at wavelengths in the range of 100 $\mu$ m were then produced by this same polishing technique. The starting material used for these final detector wafers was the same Ge:Ga material NASA has previously used for Ge:Ga far infrared detectors in many other far

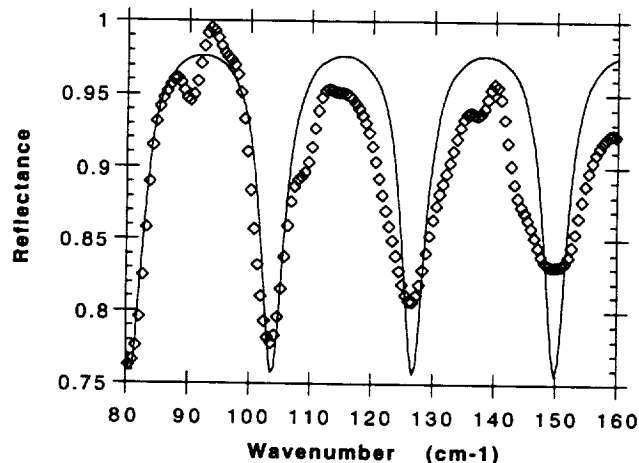
infrared investigations (LBL crystals #112 and 113). This rather precious material then awaited perfection of the other steps necessary to achieve the resonant detector required for this study.

Ion implanted contacts were produced on a number of polished slices using 25keV boron ions of various fluences, followed by post-annealing of the ion-damaged Ge wafers to produce fully ohmic electrical contacts. These implanted wafers were tested for transmittance, reflectance, and absorbance using the far IR spectrometer at Ames. The required ion implant doses were decided based upon these studies, and ion implantation of the final wafers has been requested to be performed by LBL at the final dose. This step has not yet occurred due to time constraints on the ion implanter and operators, so final unit quantum efficiency devices will not be delivered until early FY93. However, this does not impede the testing of non-contacted wafers. These latter devices have been produced without ion implants for the purpose of determining by reflectivity studies in the Ames spectrometer whether the 100% absorption condition has been achieved. Tuning of the reflectivity of the front surface is still required, however, and is currently under way.

Measurements of surface reflectivities of gold-coated surfaces (the material of choice for far IR reflectivity with low absorption loss) was initiated using the Ames spectrometer in both transmission and reflection modes. Initially, Mylar substrates were used for ease of testing and low cost but Ge, as well as Si, substrates were eventually gold coated and tested in the spectrometer.

Curves were produced of the functional dependence of the reflection from gold coated surfaces on the thickness of the coating. For reflectivities in the 90-98% range, which are required for most of the Ge:Ga dopings used in this study, gold thicknesses in the 90-100 Angstrom range are required. Initial problems with wetting of the Ge surface by the very thin gold layers now seem to be overcome by incorporation of a low percentage of palladium into the gold films. This prevents the gold from forming islands on the surface at these low coverages. A precise estimate of the necessary gold thickness for the required reflectance to match a Ge:Ga wafer's optical absorbance per pass can now be made. The required amount of gold can be reliably evaporated by electron beam technology in high vacuum to achieve a precisely measured thickness of reflecting layer. This can then be used on the final wafer slices to produce the final detectors. In the absence of these final results, we have still been able to measure, by reflectance alone, the absorption of light at the resonant wavelength on samples with non-optimized dopings and gold coatings. These spectra,

such as in the figure, show the resonant increase in the absorption which leads to the final desired effect of unit quantum efficiency in a fully optimized final detector.



*Reflectance of a 66 $\mu$ m-thick Ge:Ga wafer measured at room temperature. The wafer was boron implanted for contact electrodes and was gold coated on the back side for 100% back surface reflectance. The solid curve represents the theoretical calculations based on a 5% absorption per pass. The deviation from theoretical values at higher wave numbers is expected and is due to room temperature Ge phonon absorption.*

Since the final detectors will be operated at liquid helium temperatures, as required to obtain a photoconductive signal, the reflectance of the coated samples had to be measured at the same temperatures in order to achieve the proper absorption of far IR light by the gallium dopant in the Ge. A specialized dewar was constructed and optimized, including both physical and optical interface to the spectrometer, to allow parallel beam reflectance testing at wavelengths of the order of 100 microns. This apparatus has been produced and tested here at Ames on our spectrometer, and has been shown to give good results in terms of spectroscopy. This apparatus will be used for final testing of the final detectors when the proper ion implantation and gold evaporations have been performed.

### Significance of results

The most significant aspect of the results of this work is the clear indication that unit quantum efficiency can be achieved by proper tuning of the reflectance to the linear absorbance of the detector slice. This can be seen clearly by the reflectance spectra in which the absorption due to an optically very thin slice of



photoconductor material produces absorption dips of significant magnitude. A fully optimized detector, with properly tuned reflectance and detector thickness, should achieve the goal of 100% quantum efficiency. This detector would allow the astrophysics community the increased signal-to-noise ratio and, correspondingly, decreased observation time which leads to the most sensitive detection of faint astronomical sources. In many cases, a low quantum efficiency detector simply will never achieve a reasonable signal-to-noise ratio (no matter how long the observation time is), due to electronic and other noise limitations. The unit quantum efficiency resonant detector will be able to achieve background limited performance (BLIP) at the selected wavelength of interest.

#### **Publications or reports resulting from study**

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# Investigation of the Scales of Turbulence in Hypersonic Rarefied Flow

## Investigator(s)

William J. Feiereisen, Ames Research Center,  
Moffett Field, CA 94035-1000  
Donald Baganoff and Sanjiva Lele,  
Stanford University, Stanford, CA 94305

## Other personnel involved

Avijit Goswami, Stanford University,  
Stanford, CA 94305

## Objectives of the study

Turbulent flows are composed of eddies of a wide range of sizes. Direct simulations attempt to accurately reproduce all of the size and time scales in a flow, against which turbulence models may be compared or turbulent flow physics studied. Similitude arguments traditionally have been employed to estimate this range of scales and have led to conclusions that the smallest spatial scales in the flow, characteristic of the eddies which dissipate the turbulent kinetic energy, are much larger than the mean free path and, therefore, viscous shear stress and heat transfer as modeled by the Navier-Stokes equations are properly represented. The parameters of these arguments have been chosen to represent normally encountered turbulence consistent with flows of engineering interest such as aircraft or turbomachinery.

For hypersonic vehicles that fly in the upper atmosphere, it is appropriate to reassess these arguments to determine if turbulent flow can exist under conditions in which the smallest scales are no longer properly modeled by the linear transport terms of the Navier-Stokes equations. If turbulent flow can exist at the low Reynolds numbers in this flight regime, then a straightforward argument suggests that the smallest eddies are in the free-molecular/continuum transition regime, and a stochastic direct simulation would be required to properly represent the turbulent dissipation. In this light, the purpose of this proposed work is to investigate the following three questions: (1) Can turbulence exist under conditions corresponding to high speed flight in the upper atmosphere? (2) Do the dissipation length scales become of the same order of magnitude as the mean free path, and what implication would this have for the modeling of these scales? (3) Can a Monte-Carlo simulation method be used to produce a direct simulation of turbulent flow under rarefied conditions?

## Progress and results

Our initial study involved simulations in two dimensions, recognizing that turbulent physics requires the third dimension. Identical fields of isotropic homogeneous turbulence were created to use as initial conditions for a spectral Navier-Stokes code and for a discrete particle simulation code. The initial fields consisted of velocity, state of stress, density and temperature. Three dimensionless parameters control the behavior of the simulated flow. These are the rms turbulent Mach number, the ratio of the wavelength of the dominant eddy to the size of the box, and the Knudsen number given by the ratio of the mean free path length to the size of the box. In the initial study the first two parameters were held fixed, while the Knudsen number was varied from  $1/64$  to  $5/64$  to span the transition regime from continuum to rarefied. The fixed rms Mach number was set at 0.4 and the wavelength of the dominant eddy was set at one-half of the box length.

Figure 1 gives the results for the initial test and shows nearly perfect agreement for the decay of the rms turbulent kinetic energy versus time for the two values of the Knudsen numbers studied. Similar results were also obtained for the rms vorticity and rms fluctuating pressure.

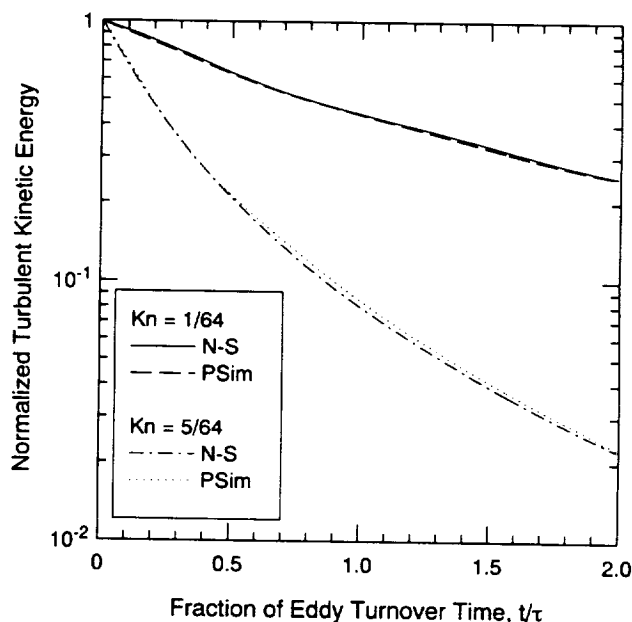


Figure 1. Decay of the rms turbulent kinetic energy versus time, for continuum and rarefied conditions.

**Significance of the results**

Considering the huge difference between the two methods of simulation, it is truly astonishing that such close agreement is obtained in both regimes. If such agreement continues to be found as all parameters are varied and fully explored, or even if certain conditions are found for which they differ, the knowledge gained will have a strong impact on both understanding and future modeling of turbulent flows.

**Publications resulting from study**

Goswami, A.; Baganoff, D.; and Lele, S.: Stanford University, Feiereisen, W., NASA-Ames, A comparative study of turbulent decay using Navier-Stokes and discrete particle simulations, 45th Annual Meeting, Fluid Dynamics Division, American Physical Society, November 22-24, 1992, Florida State University.

**References:** None so far

# Fully-Coupled Structural Deformations and Computational Fluid Dynamics: Direct Solutions Using Newton's Method

## Investigator(s)

Fort Felker, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

The objective of this research was to develop a procedure for the direct solution of static aeroelasticity problems. A direct solution obtains the equilibrium solution without using a time-marching method. The accuracy, efficiency, and convergence properties of the method were studied using a representative model problem.

## Progress and results

The research has been completed. The direct solution method was able to reduce the residual of the aeroelastic system to machine zero in less than 10 iterations, and with substantially less computer time than line Gauss-Seidel, which is a conventional time-marching technique (see fig. 1). Additional efficiency gains were obtained using a modified Newton

method, where the system Jacobian was only computed and factored once.

The efficiency of the direct solution technique for static aeroelasticity problems was also found to depend upon the data structure used in the analysis. Two data structures were considered, and a data structure with the structural variables interleaved with the fluid dynamic variables was found to minimize computational resource requirements.

Sample results for a transonic convergent-divergent nozzle are shown in figure 2, with the nozzle center-line Mach number shown for cases with rigid walls and various levels of wall flexibility.

## Significance of the results

The direct solution approach has been demonstrated to be a viable alternative to the traditional time-march procedure. The direct solution technique provides converged results in 10 iterations or less. Conventional techniques for static aeroelasticity problems can require hundreds or thousands of iterations to achieve convergence. Also, the use of Newton's method allows

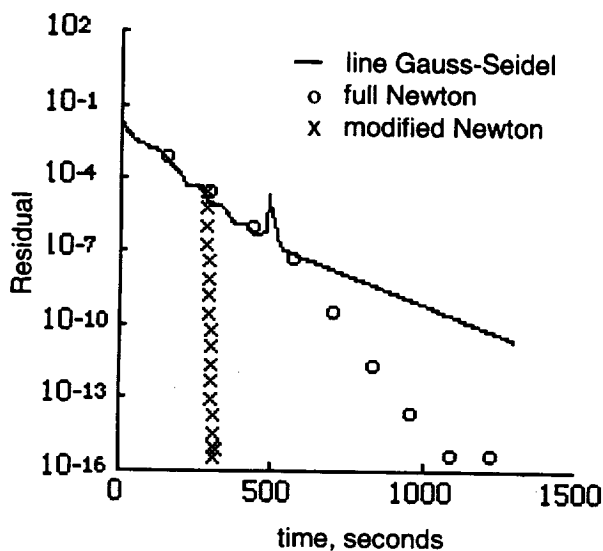


Figure 1. Comparison of convergence history obtained using various numerical techniques.

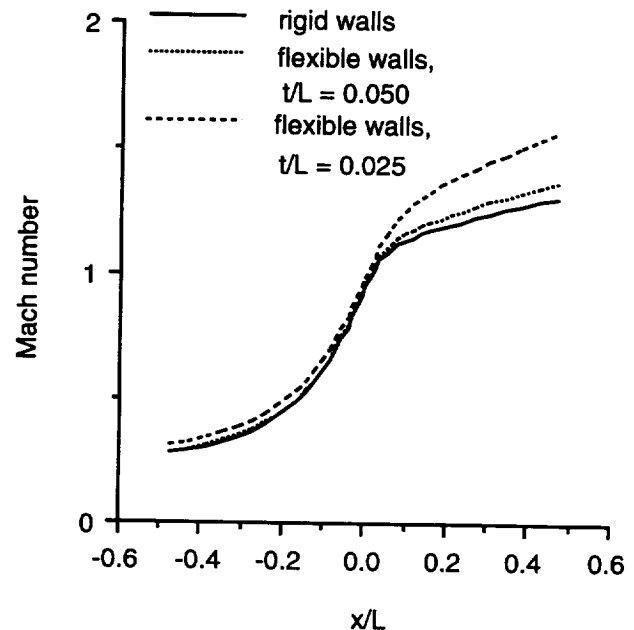


Figure 2. Comparison of predicted centerline Mach number with rigid and flexible walls.

for new capabilities, including the straightforward addition of new physical phenomena into the model, or optimization of the aeroelastic system.

#### **Publications resulting from study**

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4. Felker, F. F.: A New Method for Transonic Static Aeroelasticity Problems, AIAA Paper No. 92-2123, April 1992.

**References:** None so far

# Analytical and Experimental Studies of Rotorcraft Vertical Climb Performance

## Investigator(s)

Fort Felker, Ames Research Center,  
Moffett Field, CA 94035-1000  
Robert McKillip, Continuum Dynamics, Inc.,  
Princeton, NJ

## Objectives of the study

The objective of this research is to provide accurate methodology for the prediction of rotorcraft performance in vertical climb. It is not uncommon for the most widely-used vertical climb performance analysis method (momentum theory) to over-predict by 50% or more the power increment required to climb. The approach of the research is to first acquire high-quality experimental data on the performance and wake geometry of a representative rotor, and then to use that data to guide the development of an accurate analysis.

## Progress and results

During FY92 the experimental phase of the research was completed. Thirty-six runs with various rotor

thrusts and climb velocities were completed at the Princeton Long Track facility. Simultaneous measurements were made of rotor thrust, torque, climb velocity, rpm, and wake geometry (using smoke flow visualization). Data reduction is presently in progress.

## Significance of the results

The experimental data contain the first measurements of rotor wake geometry in vertical climb. Correct prediction of the wake geometry is the key to accurate predictions of rotor power in vertical climb. Also, the experimental approach is to use a moving model in still air. This eliminates the uncertainties associated with wind tunnel wall corrections and provides the highest-quality rotor performance data yet acquired in vertical climb.

**Publications resulting from study:** None so far

**References:** None so far

# Continuous-Flow Apparatus for Studies of Gas- and Liquid-Phase Adsorption Dynamics

## Investigator(s)

John E. Finn and Sanford S. Davis,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Karl Amo, Bionetics Corporation,  
Mountain View, CA  
Ileana Constantinescu, De Anza College,  
Cupertino, CA  
Phuong Nguyen, De Anza College,  
Cupertino, CA

## Objectives of the study

Several life support technologies that will enable long duration (more than one year) space missions depend on adsorption processes to purify air and water. Adsorption units are typically simple in concept and operation: a fluid stream containing a large variety of contaminants passes through a sorbent or ion exchange bed; the bed adsorbs unwanted organic molecules and/or ions; and the purified fluid proceeds to the next stage of the system or re-enters the cabin. Over time, the bed becomes saturated with contaminants and must be regenerated or replaced.

The simplicity of the bed veils a rich and sometimes surprising behavior. Contaminant species, often quite dilute in the fluid phase, concentrate on the sorbent surfaces. There these species interact with each other, sometimes enhancing, but often impairing, the ability of the bed to remove particular contaminants. Accurate modeling of adsorption bed behavior is essential for the proper design of life support systems, for predicting exigent situations in flight, for reliable troubleshooting of life support problems, and for crew safety in general. The complex chemistry and physics of the bed makes this a challenging problem.

We have started with a mathematical model of a one-dimensional (axial) trace gas adsorption column that captures the important effects of diffusion, convection, adsorption, and interactions between adsorbed species. The model consists of a set of  $N$ -coupled, nonlinear, partial differential equations, where  $N$  is the number of chemical species in the fluid stream. We solve this model with high numerical accuracy using a recently developed finite difference technique. For validating the model and the simulation method, we have designed an experimental

adsorption dynamics apparatus that enables precise control of operating conditions and continuous and simultaneous monitoring of many chemical species in the adsorption column effluent. Equilibrium adsorption experiments and multi-component adsorption theory provide required physical information about the test system.

## Progress and results

The adsorption column model takes the form

$$I \frac{\partial c}{\partial t} - \frac{1}{Pe} \frac{\partial^2 c}{\partial z^2} + \frac{\partial c}{\partial z} + A \frac{\partial c}{\partial z} = 0, \quad A_{ij} = \frac{(1-\epsilon)}{\epsilon} \frac{\partial q_i}{\partial c_j},$$

$i, j = 1 \dots N$ , with initial/boundary conditions  $c_i(z, t = 0) = c_{i,0}(z)$ ,  $c_i(z = 0, t) = c_{i,inlet}$ , and  $\partial c_i / \partial z|_{z=L} = 0$ .  $c$  is concentration,  $t$  is time,  $z$  is distance down the bed, and  $\epsilon$  is the void fraction. The axial Peclet number ( $Pe$ ) divides the product of the length of the bed and the interstitial fluid velocity by the axial diffusivity. The matrix  $A$  couples the equations together strongly; this term incorporates multicomponent adsorption equilibria ( $q$ ) and intraparticle diffusion.

The numerical algorithm solves the dominant advection problem using a 4th-order-accurate discrete dispersion relationship (refs. 1,2) for a set of coupled equations. This relatively new technique contributes no numerical (artificial) diffusion. The diffusive part is solved with the standard Crank-Nicholson method (ref. 3). Multicomponent adsorption equilibrium is calculated by ideal adsorbed solution theory (refs. 4,5). The solution of the model takes the form of  $N$  waves that pass through the bed at different rates.

An example of real adsorption column behavior that this model captures is that of contaminant "roll-up." In roll-up, weakly adsorbed species are displaced by more strongly adsorbed components. The concentration of weakly adsorbed species builds inside the column; a peak forms and eventually breaks through the column at a concentration much higher than the inlet concentration. This phenomenon has an obvious impact on life support system design. Figures 1 and 2 display simulation results that illustrate this behavior.

Figure 1 shows column effluent as a function of dimensionless time for two trace gases in a carrier gas. At first both gases are removed, but at approximately  $t = 0.5$  the weakly adsorbed species breaks through at

300% of its inlet concentration. To understand better why this happens, we examine the intracolumn waves shown in figure 2. This figure shows how the roll-up wave grows and eventually breaks through the column.

The assembly of the experimental apparatus is nearly complete. The apparatus will consist of a mixing manifold in which gases are combined in precise fraction and flow rate, a constant temperature chamber which houses the adsorption column(s) at a specified temperature, and a mass spectrometer that analyzes the column effluent for many chemical species simultaneously and continuously.

While the mass spectrometer has not yet arrived, we presently use a flame ionization detector to monitor the column effluent for some simple mixtures. This enables us to check certain dynamic aspects of our

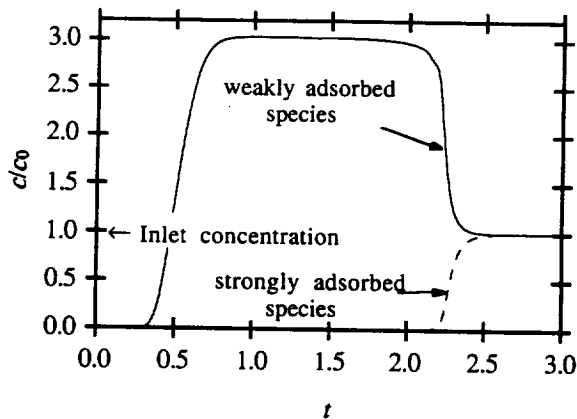


Figure 1. Simulation results for column effluent exhibiting 300% roll-up.

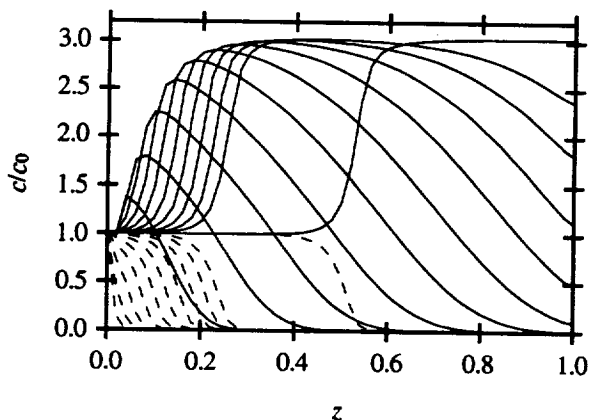


Figure 2. Results of same simulation showing snapshots of intracolumn wavefronts at evenly-spaced time intervals. Weakly adsorbed species (solid line), strongly adsorbed species (dashed).

model. An example comparison between model and experimental results is displayed in figure 3. For this example the simulation code was provided pure component isotherms and column and flow parameters. This excellent fit to the experimental results was obtained by adjusting the axial diffusivity to  $0.5 \text{ cm}^2/\text{s}$ , which agrees well with published correlations for packed columns (ref. 6).

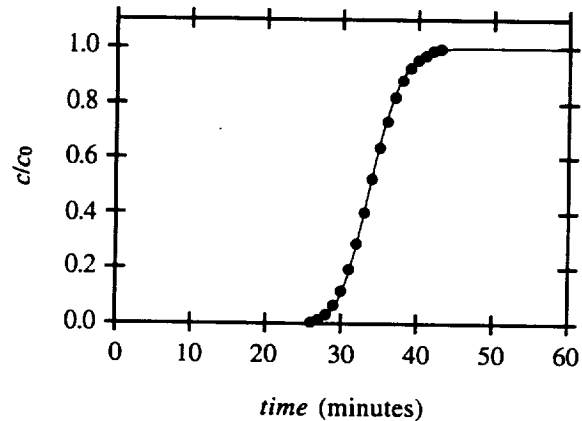


Figure 3. Comparison between model (solid line) and experimental (points) column effluent results for the system 0.26% ethane in nitrogen on 13X zeolite molecular sieve,  $50^\circ\text{C}$ , 1 atm pressure.  $10 \text{ cm} \times 1 \text{ cm}$  column, flowrate  $200 \text{ cm}^3/\text{min}$  (STP).

### Significance of the results

Accurate modeling and process simulation of sorption columns is essential for the safe design and operation of life support systems for long missions, as the range of possible circumstances that may be encountered is too large to investigate through experiments alone. At this time we have developed a highly accurate numerical algorithm and thermodynamically consistent simulation code for adsorption columns, and have begun validation experiments using the apparatus. Preliminary results are favorable and allow us to proceed to the next steps of multicomponent and liquid-phase experiments.

**Publications resulting from study:** None so far

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# Development of Modal Filtering Techniques for On-Line Estimation of Structural Vibration Parameters

## Investigator(s)

Lawrence C. Freudinger,  
Ames-Dryden Flight Research Facility,  
Edwards, CA 93523-0273

## Other personnel involved

Stuart J. Shelley and Randall J. Allemang,  
University of Cincinnati,  
Cincinnati, OH 45227-0072

## Objectives of the study

Monitoring the dynamic characteristics of a vibrating mechanical system is currently a time consuming and expensive undertaking, but is often necessary from a safety or health maintenance perspective. A specific example familiar to the investigator is flight flutter testing and aeroservoelastic flight testing of aircraft. The objective of this work is to develop a new concept (called *discrete modal filtering*) for the purpose of monitoring the vibration characteristics of mechanical systems. More specifically, the primary goal is to develop a tool that allows easy implementation of on-line vibration parameter estimation schemes and to use this tool to measure the performance gains possible through the use of discrete modal filters.

Discrete modal filters are essentially *coordinate transformations* that take advantage of certain properties of a mechanical system's vibrating shapes (modal vector orthogonality) in order to separate and condense measured information into simple and more meaningful data.

## Progress and results

The theory of adaptive modal filtering was presented in a conference paper as was the strategy for implementing estimation schemes on-line.

A main obstacle to implementing on-line schemes, that was overcome this first year, was that hardware-based coordinate transformations were not available from off-the-shelf data acquisition packages. This was an important issue because it may be desirable to place dozens or perhaps hundreds of sensors on a structure when only a few really meaningful streams of information are to be extracted by the modal filters. Thus, hardware-based modal filters are needed to reduce the computational load on the computer analyzing the data.

To solve this problem, a computer program was written which controls sophisticated data acquisition hardware and which performs the modal filtering before passing the data to the computer. Also, this software is controlled from within a very flexible and widely used matrix manipulation software environment which makes implementation of on-line estimation schemes straightforward.

As an example of its operability, a simple estimation algorithm that utilized the discrete modal filter for a somewhat complicated truss structure successfully tracked changing vibration parameters when that structure was modified in an abrupt fashion.

## Significance of the results

The results of this development thus far indicate that there are no major roadblocks to the success of this effort.

From a broader perspective, sophisticated dynamic testing and health monitoring of vibrating structures is often beyond the financial reaches of many potential beneficiaries. This development is laying the groundwork for significantly improved testing methodology while simultaneously reducing the cost of testing. In the case of aircraft ground vibration and flight flutter testing, it is believed that this work will indeed result in tools and techniques sufficiently inexpensive to be adopted by the commercial and general aviation industry. This will ultimately contribute to increased passenger safety and economic competitiveness for those manufacturers.

## Publications resulting from study

Freudinger, Lawrence C.; Shelley, S. J.; and Allemang, R. J.: *On-Line Parameter Estimation Using the Discrete Modal Filter*, final report for NASA Ames Research Center University Consortium, Interchange NCA2-642, June 1992.

Shelley, Stuart J.; Freudinger, L. C.; and Allemang, R. J.: *Development of an On-Line Parameter Estimation System Using the Discrete Modal Filter*, Tenth International Modal Analysis Conference, San Diego, CA, February 1992, pp. 173-183.

**References:** None so far

# Computational Modeling of Femtosecond All-Optical Switches Directly from Maxwell's Equations

## Investigator(s)

Peter M. Goorjian, Ames Research Center,  
Moffett Field, CA 94035-1000  
Allen Taflove, Northwestern University,  
Evanston, IL 60208

## Other personnel involved

Rose M. Joseph and Susan C. Hagness,  
Northwestern University, Evanston, IL 60208

## Objectives of the study

Intensive activities are under way in photonics to develop all-optical switching devices. The applications are to advanced digital signal processors and optical computers. Optical processors are potentially 1,000 times faster than electronic computers. They are expected to be capable of  $10^{13}$  operations per second, compared to  $10^{10}$  operations per second of current electronic computers, such as the Cray-90. Optical signal processors could interface directly with ultra-wideband optical fiber communications systems. The main development that is needed for optical circuits is to develop femtosecond all-optical switches and logic gates.

The need for a new algorithm to aid this research is based on the following considerations. Laboratory construction alone without computer simulations would be prohibitively lengthy and costly. However, current computational and analytical methods use the nonlinear Schrodinger Equation (NLSE), a scalar equation, to approximate Maxwell's equations, a system of vector equations. Hence the NLSE neglects the vector wave effects. Also the NLSE omits the optical carrier of the electromagnetic pulse. By using the full vector nonlinear Maxwell equations, the electromagnetic field can be more accurately modeled in applications to 2-D and 3-D integrated optical circuits with characteristic dimensions close to the optical wavelength.

This study has the following objectives. The initial goal is to develop algorithms and computer codes for modeling femtosecond all-optical switches and logic gates on a 10-nanometer distance scale with the full-vector, nonlinear Maxwell equations. As part of this objective, a capability will be developed to model nonlinear optical materials, including linear and nonlinear, instantaneous and dispersive effects in the

electric polarization in material media. The next step will be to develop a capability to model millimeter-scale 2-D and 3-D integrated optical circuits. In this stage the optical carrier of the electromagnetic field will be retained. In this way, interactions of the pulses with geometry features on the size of the optical wavelength, such as material inhomogeneities (e.g., crossing fibers), can be accurately modeled. The final step will be to use the codes to develop candidate designs for femtosecond all-optical switches, logic gates, and ultimately integrated optical circuits.

## Progress and results

The first algorithm has been developed that solves the full-vector Maxwell equations in nonlinear dispersive optical materials. The modeling includes the optical carrier of a signal. Also the modeling includes the nonlinear quantum effects such as the Kerr and Raman interactions.

The capability of the algorithm has been demonstrated by the calculation of 1-D and 2-D propagating and colliding femtosecond optical solitons that include the carrier wave. These calculations show the phase modulation of the carrier waves by the collision. Such modulation may form the basis of a switching mechanism.

Figures 1 through 4 show two-dimensional calculations of the collision of counter-propagating solitons. They show the electric field along the centerline of a slab waveguide. The electric field values are normalized by the maximum amplitude of the two equally sized solitons as they enter from the boundaries.

## Significance of the results

These calculations in 1-D and 2-D of propagating and colliding solitons show that this algorithm has the capability of modeling electromagnetic fields in nonlinear optical materials. The modeling is fairly complete in that it includes the carrier wave, the full vector electromagnetic field, and the quantum effects of the Kerr and Raman interactions. Upon further development of the geometric capabilities, this algorithm will be able to model optical devices such as optical switches. The resulting code can then be used in a design mode to aid the laboratory fabrication of such devices.

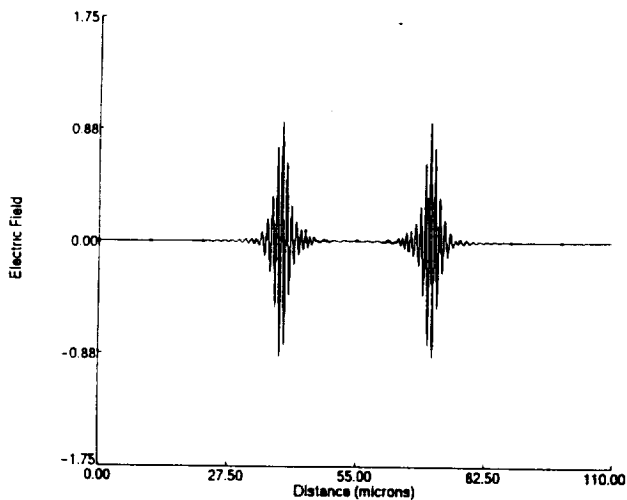


Figure 1. Collision of counter-propagating solitons. Approaching,  $T = 9,200 \Delta t$ .

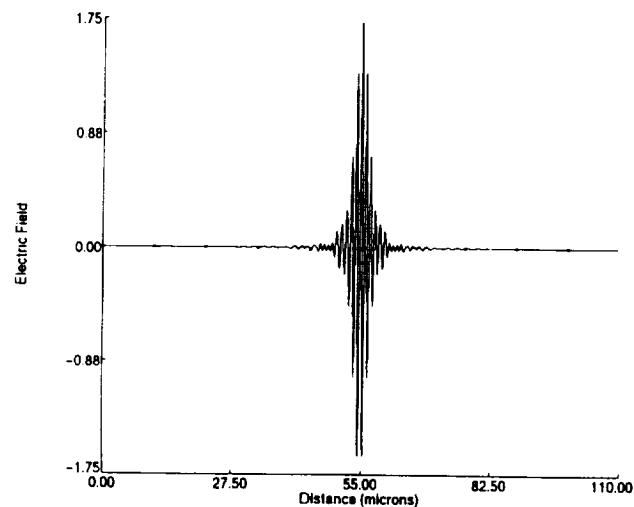


Figure 3. Collision of counter-propagating solitons. Constructive interference,  $T = 12,444 \Delta t$ .

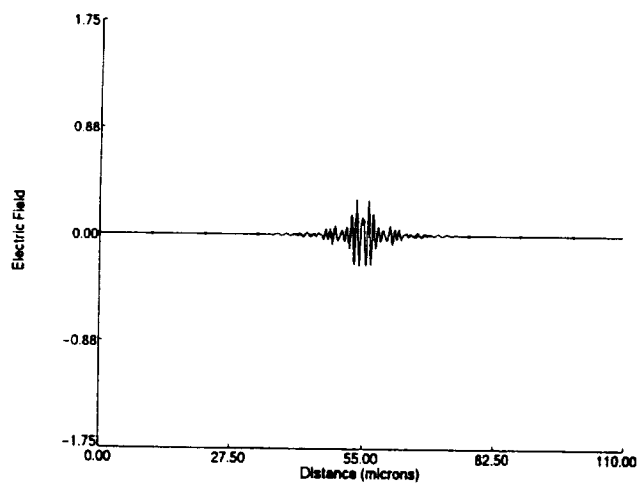


Figure 2. Collision of counter-propagating solitons. Destructive interference,  $T = 12,420 \Delta t$ .

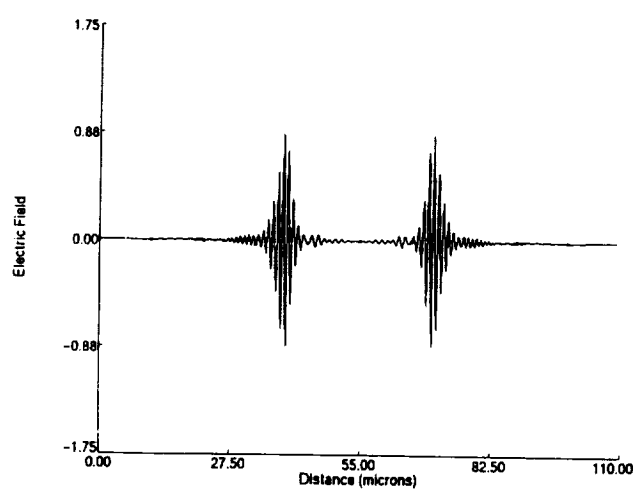


Figure 4. Collision of counter-propagating solitons. Separating,  $T = 15,800 \Delta t$ .

### **Publications resulting from study**

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3. Goorjian, P. M.; Taflove, A.; Joseph, R. M.; and Hagness, S. C.: Computational Modeling of Femtosecond Optical Solitons from Maxwell's Equations, IEEE Journal of Quantum Electronics, special issue on Ultrafast Optics and Electronics, vol. 28, no. 10, pp. 2416-2422, Oct. 1992.

**References:** None so far

# Gravity Modulation of Tension/Compression Effects on Cellular Responses

## Investigator(s)

Rose Grymes, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Christine Sawyer, Ames Research Center,  
Moffett Field, CA 94035-1000  
Maronda V. Brown, Morris Brown College,  
Atlanta, GA

## Objectives of the study

The architectures of living systems perceive both load-bearing and tension/contraction stresses. Gravity has played a fundamental role in the ontogeny of these systems, and acts as a constant input modifier. The effect of altered gravities on wounding/healing responses in normal fibroblasts and keratinocytes is being investigated. Tension/compression stresses, as part of a continuum of environmental forces experienced by cells, are studied by pre-growing cells in a Flexcell® unit. This apparatus is a new technology that uses flexible-bottom culture plates, coated with collagen or other matrix macromolecules, to transfer cyclic tension to adherent cultured cells. Regulated, reproducible stresses are induced in culture plates positioned on a gasket support connected to a vacuum pump. This research will generate a spectrum of data relevant to gravitational biology, wounding/healing, and tensional stress.

## Progress and results

Appropriate cell cultures have been acquired and established under normal 1-G laboratory conditions. We have assessed their growth characteristics, in both the control (rigid plastic culture dishes) and the test (flexible bottomed culture dishes) conditions. We have generated detailed growth curves for three different cell strains, representing cells of different lifespans and growth potentials. The data have been cross-checked using both cell counts and DNA synthesis (measured by the incorporation of <sup>3</sup>H thymidine precursor). Specific manufacturer's "lots" of the growth factors platelet-derived growth factor (PDGF) and epidermal growth factor (EGF) have been assayed for their respective abilities to stimulate DNA synthesis, cell growth, and cell division.

Prior to experimental treatment, we find that it is essential to adapt the cells to the flexible membrane by

inoculating them for one cell passage on a large version of the Flexcell® plates. The cell population assumes a changed colony morphology under these conditions. Even in the absence of applied stress, the cultured cells align with their neighbors that have increased affinity. In contrast, cells cultured in our prototype clinostat unit under conditions of continual vectorial gravity shift show a marked tendency towards the development of population "islands" with disorganized morphology.

We proposed to examine our samples using photomicroscopy. We acquired a phase-contrast inverted microscope with camera attachment for this work, and have documented the observations on growth characteristics detailed above. In the arena of fluorescent-antibody stains for the localization of cytoskeletal components, preliminary samples are being analyzed. A new collaborator, NASA-JOVE fellow, M. V. Brown, is an experienced microscopist. In addition to her work with fluorescent reagents, she adds the ability to analyze our cells using electron microscopic techniques to reveal cellular ultrastructure. To screen for the expression of growth regulatory genes/proto-oncogenes, we have acquired and tested oligonucleotide probes.

## Significance of the results

The importance of physiologic tensional stresses has been demonstrated both *in vivo* and *in vitro*. The cytoskeleton receives and transmits environmental stimuli, including growth factor responses and matrix interactions. It is both a structure of morphology and a transducer of information. As a component of structural integrity, this architectural complex is ideally suited to sense the physical changes associated with altered gravities. Our studies in FY92 provided a solid foundation in assessing our model system. We understand the growth characteristics of our cells, the fundamentals of a very complex new technology (the Flexcell® unit), and have put in place the reagents and protocols required. Figure 1 shows graphically (on the left) and descriptively (on the right) the production of stress in the flexible culture membranes. Figures 2 and 3 demonstrate the method by which we intend to examine our growing cultures in the next FY, after acquisition of an epifluorescence upgrade for our microscope. Preliminary results conform to predictions made from our hypothesis. Cells grown at 1-g on the Flexcell® plates experienced heightened polarity

sensitivity, compared with cells grown on rigid plastic supports and subjected to continuous vectorial gravity change. Our research will continue in FY93.

**Publications resulting from study:** None so far

**References:** None so far

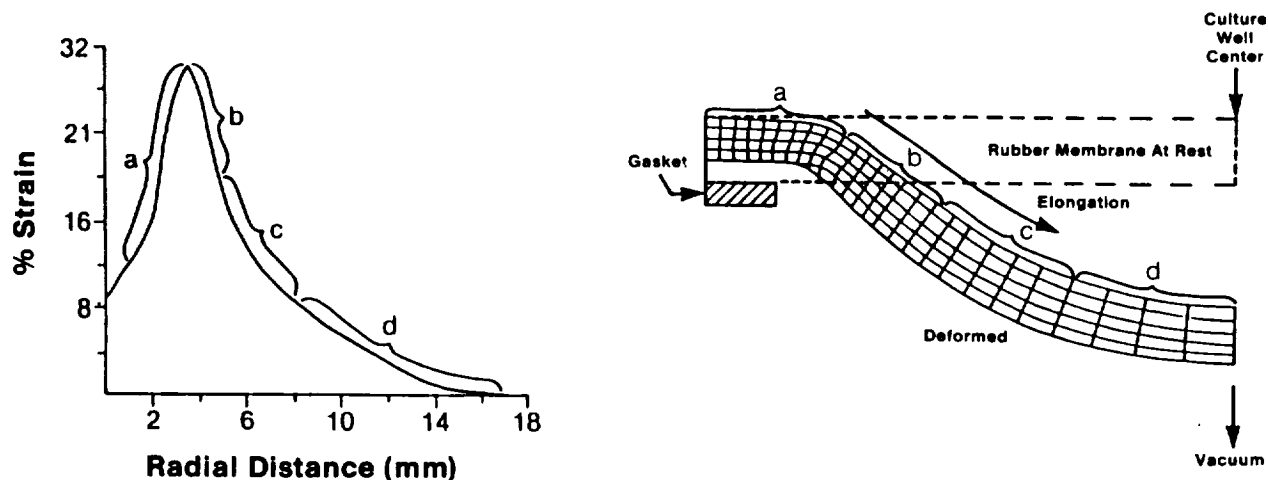


Figure 1. Description of stress generation in flexible membranes.

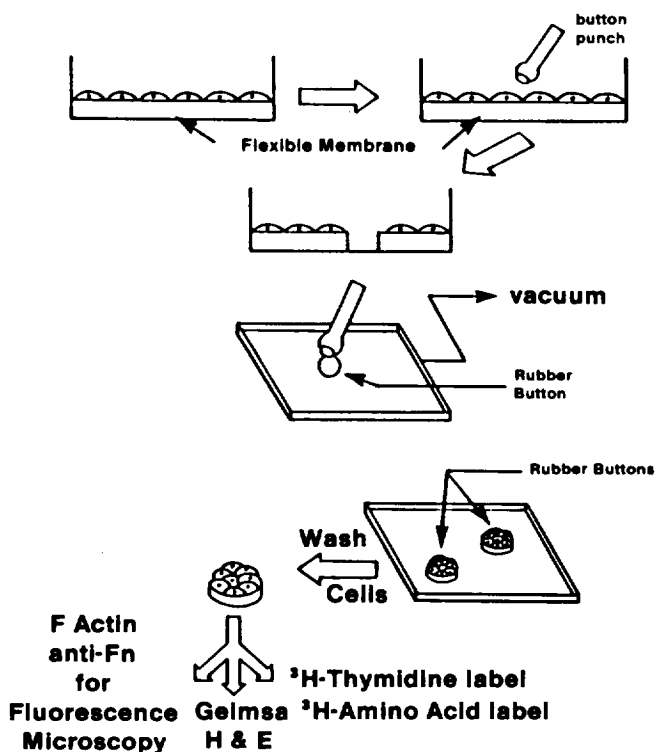


Figure 2. Methods for removing rubber buttons from a Flex 1™ culture plate substratum.

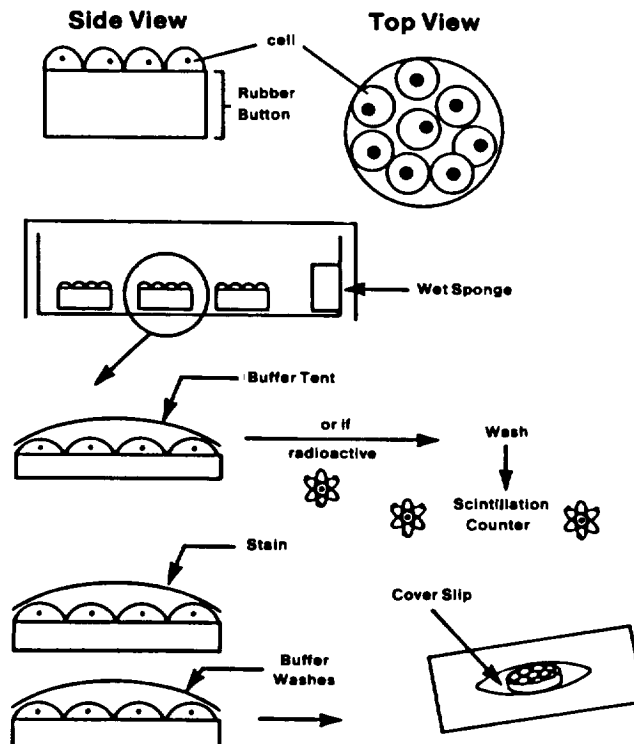


Figure 3. Staining cells on a rubber button.

# Domain Decomposition Approach to Solve Multidisciplinary Fluid/Structure Interaction Problems

## Investigator(s)

Guru P. Guruswamy, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Chansup Byun, MCAT Institute, San Jose, CA  
Rakesh Kapania and Dale MacMurdy,  
Virginia Polytechnic Institute, Blacksburg, VA

## Objectives of the study

In recent years significant advances have been made in the separate disciplines of both computational fluid dynamics (CFD) and computational structural dynamics (CSD). However, only a limited amount of work has been completed in combining these two disciplines. This is mainly because of the lack of new ideas about combining the two major computational fields as well as the increased level of complication associated with a multidisciplinary approach. In this work a computational technique is initiated to combine a finite-difference CFD technique with a finite element CSD technique to study the fluid/structure interactions of aerospace vehicles. This capability will significantly impact many aerospace projects of national importance.

The research conducted under this proposal primarily addresses the interface algorithms between the fluid and structural domains. This work will greatly enhance the capability to accurately predict aeroelastic instabilities which can not be predicted by single discipline CFD and CSD simulations. It will also provide an insight into the development of a general purpose computational capability to solve multidisciplinary problems.

In this project two techniques are developed for interfacing between the fluid zonal grids and structural sub-domains (sub-structures). These interface techniques are tested on simple model problems. Procedures to use this concept to solve larger three-dimensional problems are addressed in the proposed paper based on this work.

## Progress and results

In this work, the fluid and structure are solved in separate computational domains. The flow is modeled using the Euler/Navier-Stokes equations. The structure of the selected configuration is modeled using the

finite-element equations. The information between two domains is transferred using (1) consistent load approach and (2) virtual surface approach.

In the consistent load approach, the pressure data from the flow computations are interpolated to the finite-element grids, and consistent loads are computed using the finite element approach. Using the consistent loads, the displacements are computed on finite-element nodes and are interpolated back to FD grids. This approach is successfully applied for the wing problems using wing-box FE (ref. 1) and wing-body problems using beam elements (ref. 2).

In the virtual surface approach, a grid layout is selected independent of FD and FE grids. The pressure data and the displacement data are both transferred through this common interface generated once in the beginning of the computation from the coordinate information of the FD and FE grids. The order of accuracy can be increased by selecting suitable shape functions for the common surface based on the FE approach. This technique is illustrated in figure 1. This approach is successfully used to compute aeroelastic responses of wings using a plate FE modeling (ref. 3). It is planned to apply this technique for wing-body configurations using plate and shell elements (ref. 4).

## Significance of the results

The present results demonstrate application of the basic idea of interfacing the information between FD fluids grids and FE structural nodes for wings. This will serve as a "stepping stone" to the domain decomposition approach for complex configurations. This work will be extended for general aircraft configurations in future.

## Publications resulting from study

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2. Guruswamy, G.: Coupled Finite-Difference/Finite Element Approach For Wing-Body Aeroelasticity, AIAA-92-4680, 4th Symposium on Multidisciplinary Analysis and Optimization, Cleveland, OH, September 1992.



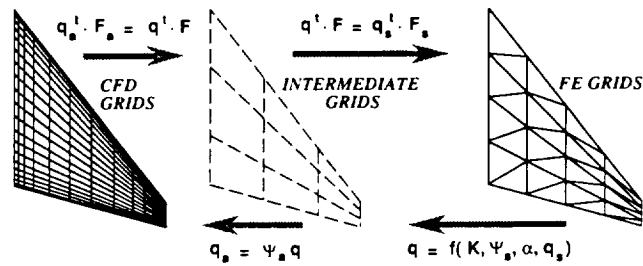


Figure 1. Fluid/structure interface.

3. Byun, C.; and Guruswamy, G.: A Comparative Study between Serial and Parallel Aeroelastic Computations on Wings, Abstract proposed for 35th AIAA Structural Dynamics Conference, April 1993.
4. Guruswamy, G.; and Byun, C.: Wing-Body Aeroelasticity Using Navier-Stokes Flow

Equations Coupled with Plate/Shell Finite Element Structures, Abstract proposed for 24th Fluid Dynamics Conference, July 1993.

**References:** None so far

# Deuterium Abundance in the Interstellar Medium

## Investigator(s)

Michael R. Haas and Alexander G. G. M. Tielens,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Edwin F. Erickson, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

Understanding the origin and evolution of the Universe is one of the key problems in astrophysics. It is generally accepted that the Universe formed with a "Big Bang" at a very high density and temperature. At that point, the Universe consisted of photons and various elementary particles. Upon expansion and cool down, these elementary particles combined and formed simple nucleons such as hydrogen and helium. Upon further expansion, under the influence of their own gravity, these atoms formed stars and these stars then nucleosynthesized the heavier elements, such as C, O, and Fe.

The early Universe can be studied through its relics, the 3 K background radiation, and the relative abundances of the isotopes of H and He. Among the latter, deuterium stands out as the most powerful constraint because it is rapidly destroyed at high nucleon densities. Thus, the D/H ratio measures the time spent at high densities; i.e., the expansion rate of the very early Universe. The goal of this research is to infer the D/H ratio from the measurement of several rotational lines of HD and H<sub>2</sub> in shocked interstellar gas. Theoretical studies have shown that the detection of these HD transitions will yield the most direct determination of the D/H ratio to date.

## Progress and results

We intend to use the Kuiper Airborne Observatory and the facility cryogenic grating spectrometer to observe several far-infrared lines of HD and H<sub>2</sub> in the Orion molecular shock. Since this proposal was just funded three months ago, only preliminary progress has been made.

In order to obtain the necessary sensitivity for these observations, we plan to replace the existing array of discrete Ge:Be photoconductor detectors with Si:Sb

back-illuminated, blocked impurity band detectors. These detectors are being developed by Rockwell International with funding from NASA's Space Infrared Telescope Facility (SIRTF) Project, but they have not been made readily available to the astronomical community at large. We are in the process of issuing a contract to Rockwell so they can fabricate some of these detectors for us. Through negotiations with Rockwell, we have established anticipated performance for these detectors which should be achievable and will satisfy the needs of this experiment.

We anticipate delivery of these devices during the first half of 1993. They will then be integrated with cold amplifiers and installed in the spectrometer for testing and calibration. In the meantime, we are making plans to submit a proposal for flight time on the Kuiper Airborne Observatory during the next review cycle.

## Significance of the results

Although observations of a plethora of deuterated molecules have already been made, the interpretation of these measurements is generally uncertain because the observed species are typically only minor reservoirs of deuterium and corrections for the unseen deuterium are substantial and largely unknown. This is contrary to the situation for warm (~500-2000 K), dense gas which has been heated by interstellar shocks. Here the deuterium chemistry is dominated by neutral-neutral reactions, in particular  $D + H_2 \rightarrow H + HD$ . The conversion of D into HD by this reaction is much faster than the shock cooling time, and all the deuterium is expected to be in the form of HD. Similarly, all the hydrogen is expected to be molecular. Since this shocked gas is warm, the emission is relatively strong, thereby presenting an excellent opportunity to probe the total gas phase deuterium abundance using observations of a single species.

**Publications resulting from study:** None so far

**References:** None so far

# Remote Sensing of Earth's Atmosphere and Surface Using a Digital Array Scanned Interferometer

## Investigator(s)

Philip D. Hammer, Francisco P. J. Valero, and David L. Peterson, Ames Research Center, Moffett Field, CA 94035-1000  
William Hayden Smith, Washington University, St. Louis, MO

## Other personnel involved

Allan Delamere, Mike Duncan, and Dave Dorn, Ball Aerospace, Boulder, CO  
Jim Miracle, Aerotech Corp.,

## Objectives of the study

Understanding complex and variable environmental phenomena inherent in Earth's atmosphere, global climate, and biogeochemical processes requires spatial, spectral, and temporal observations which are both extensive and detailed. Thus the motivation is clear for designing simple, versatile, and cost effective imaging spectrometers for Earth remote sensing applications with high spatial and spectral resolution, fast temporal response, and high detection sensitivity.

The primary objective of our study is to evaluate the capabilities of the DASI (digital array scanned interferometer) class of instruments for terrestrial remote sensing at visible to mid-infrared wavelengths. DASIs have many of the positive characteristics associated with Fourier transform spectrometers and also the capability for spatial imaging (Smith and Schempp, 1991). Thus a DASI has the potential of achieving higher spectral and spatial resolution at a specified signal-to-noise level than equivalent aperture grating based instruments such as AVIRIS (Vane, 1987). Perhaps one of the most notable features of DASIs is their ability to acquire an entire interferogram simultaneously without any moving optical elements.

The principle of DASI operation is similar to that of scanned interferometers (Caulfield, 1976). Detected signals result from two-beam interference. The wavelength spectrum of the incident radiation is obtained by Fourier transforming this recorded interferogram. Unlike a conventional interferometer, the DASI operates with its mirrors fixed in position. The range of path differences between the recombined beams is achieved by means of the configuration of the optical components so that stationary fringes of equal inclination are formed at the image plane. This comprises an interferogram which can be resolved spatially by a

detector array. The orthogonal dimension of the image plane is available for spatial imaging.

The ultimate objective is to produce and deploy a versatile field instrument which may be applied toward a variety of atmospheric and surface problems.

## Progress and results

Using our prototype instrument, spectral image measurements have been obtained of a variety of different terrestrial scenes. Image cubes of various cloud fields at different elevations and solar illumination conditions were obtained. Image cubes of landscapes and a single tree were also acquired to assess remote sensing methods for determining plant biochemical content (Peterson, 1988). Visible wavelength measurements were made using a CCD array detector, and near-infrared measurements were made with the MCT array described below.

Following are some selected results from ground based cirrus cloud measurements made using the DASI configuration shown in figure 1 (Okamoto, 1986) with a doublet lens in place of the telescope for light collection (2-cm diameter, 10-cm focal length). A short wavelength MCT array (0.8 – 2.5  $\mu\text{m}$  sensitivity) of dimensions  $256 \times 256$  pixels was used at the detector plane. Our choice of optics gave a spatial field of view of 5 degrees angular width. Three-dimensional image cubes (two spatial and one spectral) were obtained by placing a computer controlled mirror in front of the light collecting optics and scanning over the field of view in a way that swept the image across the entrance slit, push-broom style.

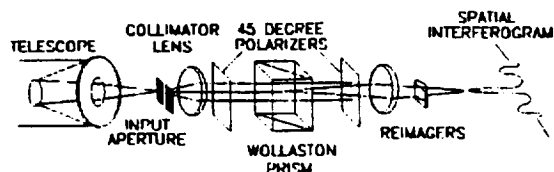


Figure 1. DASI based on a birefringent interferometer.

The computer was also used to acquire images from the array in coordination with the mirror motion. Typically 200 to 300 frames were taken to give roughly square spatial images. Detection integration times ranged from 0.2 to 1 second per frame, but the frame acquisition rate was limited by the computer speed to 1 per second. The entrance slit width was varied between 25 and 100  $\mu\text{m}$  (the former gave optimum

spatial resolution). Note that we would not expect the spectral resolution to be affected by the slit width because of the field widening characteristics of this type of DASI. The reimaging optics were chosen to give a spectral resolution of about  $300\text{ cm}^{-1}$  (30 nm at  $1\text{ }\mu\text{m}$ ). A short pass interference filter was placed inside the liquid nitrogen cooled dewar containing the array to block out most of the thermal background radiation. This limited the spectral range to 1.1 to  $2.2\text{ }\mu\text{m}$ . Thus there were about 20 effective spectral elements.

Figure 2 shows a series of spectra corresponding to a section through an image cube derived from a measurement of solar reflectance from a cirrus cloud field which was located about 20 degrees above the horizon. The variations in overall radiance reveal variations in the cirrus optical depth along a trajectory over the cirrus image.

Figure 3 shows a spectrum corresponding to a single spatial pixel along this trajectory, together with a simulated spectra produced by LOWTRAN-7 for comparison.

Another byproduct of our research has been the development of optical ray tracing software for polarized light through birefringent media. This software has aided the development of the prototype DASI described above and will serve as an indispens-

able tool in the design and optimization of future versions of the birefringent DASI instrument.

### Significance of the results

The application of DASI imaging spectrometers to remote sensing of the atmosphere at visible and near infrared wavelengths is very promising, based on our preliminary results. The image cube measurements we have described reveal the potential science yields from obtaining simultaneous high resolution spatial and spectral information for the analysis of cloud radiative interactions and physical properties. The minimum detector integration time of 0.2 second per frame shows that in principle a 5-hertz sampling rate is attainable, which is suitable for high spatial resolution airborne measurements.

The ease of construction and operation due to the absence of actively scanning optical components provides a relatively inexpensive alternative to other interferometer designs. The compactness and flexibility of DASI optical configurations enable corresponding flexibility in the design of collection optics, choice of detectors, and interfacing of data collection systems. Specifically, the spectral and spatial resolutions and ranges we have chosen for our initial measurements, as described above, could be increased substantially. Some of the features of DASIs we have

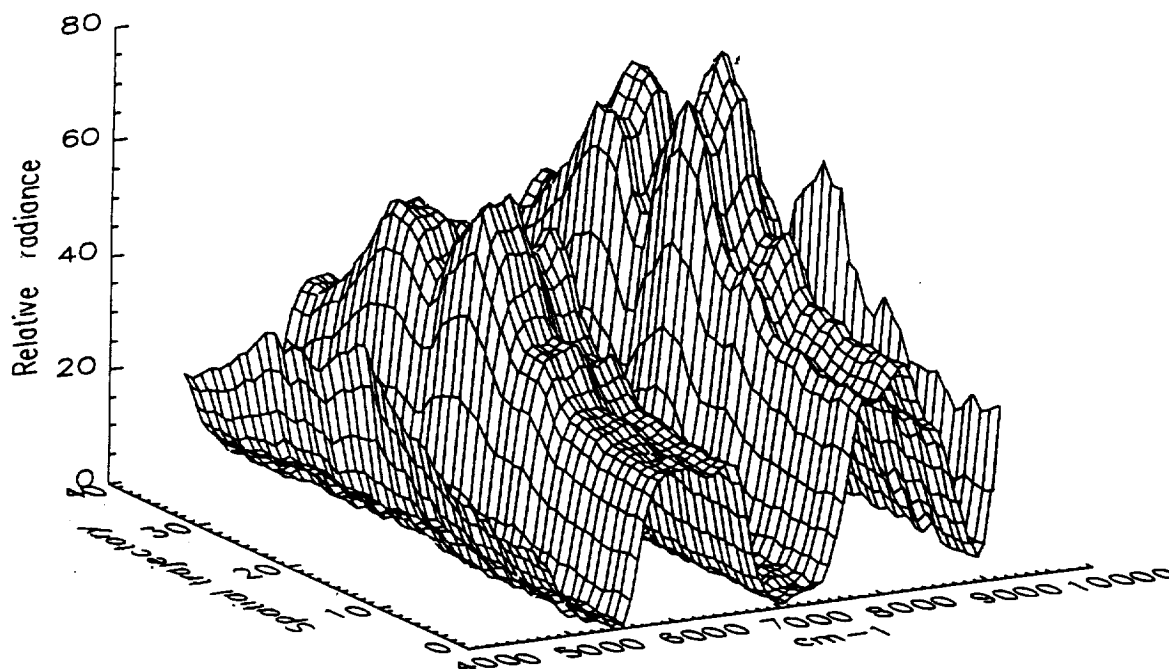


Figure 2. Spectral series corresponding to a trajectory along an image cube of a cirrus cloud field. The wave number spectral coordinate is in units of inverse centimeters. Note the strong atmospheric absorption bands at about  $5300\text{ cm}^{-1}$ ,  $7000\text{ cm}^{-1}$ , and  $8800\text{ cm}^{-1}$ . The structure at the radiance peaks is due primarily to weaker molecular vibrational overtone spectra.

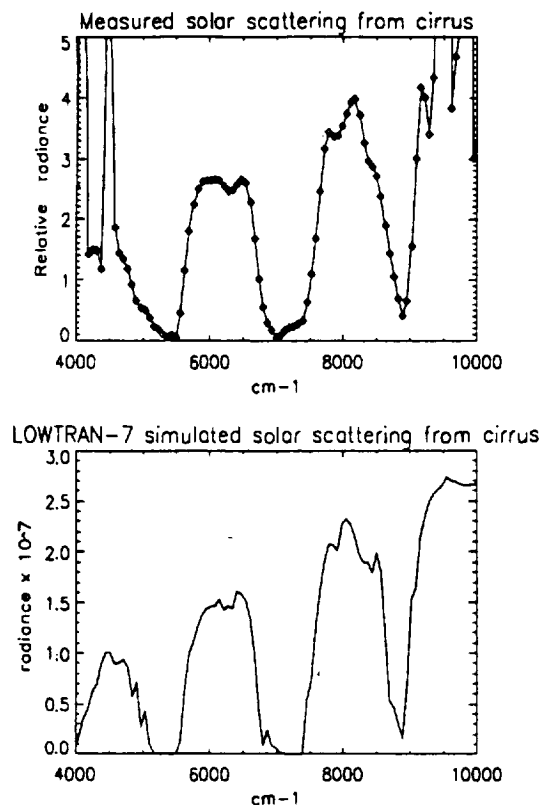


Figure 3. The upper spectrum corresponds to a spatial pixel along the trajectory represented in figure 2. The diamond symbols represent sampling points separated by  $66 \text{ cm}^{-1}$ . There is little signal outside of  $4600\text{--}9200 \text{ cm}^{-1}$  due to the filter described in the text. The lower spectrum was calculated using an estimated viewing geometry similar to that of the measurement and a sub-visual cirrus model with a cloud thickness of 2 km. LOWTRAN radiance units are  $\text{watts}/(\text{cm}^2\text{-ster}\text{-cm}^{-1})$ .

described are not practically attainable with currently available instruments.

#### Publications resulting from study

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Spectrometer. Fourth Airborne Geoscience Workshop, Jan. 29 – Feb. 1, 1991, La Jolla, CA, p. 161.

Smith, W. H.; Hammer, P.; Delamere, A.; Duncan, M.; and Dorn, D.: Recent Progress with Digital Array Scanned Interferometers (DASIs). 23rd Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society, Palo Alto, CA, Nov. 4-8, 1991.

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# Intelligent Dynamic Scheduling Algorithms for Automatic Telescopes

## Investigator(s)

Butler Hine, Mark Drummond, John Bresina, Keith Swanson, Andy Philips, Rich Levinson, and William Borucki, Ames Research Center, Moffett Field, CA 94035-1000

## Objectives of the study

There are many NASA mission scenarios in which the unattended autonomous operation of a scientific instrument is desired because of the expense of an *in situ* human operator. This is especially true for astronomical observations, in which the method of data acquisition is well suited to automatic operation. Automatic Photoelectric Photometry is currently performed with ground-based robotic telescopes at various sites around the world. These robotic telescopes perform unattended photometric measurements of stars for periods ranging from weeks to months, scheduling their observations from target lists and priorities decided ahead of time by astronomers.

Although robotic telescopes are currently in operation, they are not very sophisticated with respect to efficient target scheduling, health monitoring, or self-maintenance. While these capabilities are desirable for ground-based operation at easily accessible sites, they are critical for operation in space or other relatively inaccessible sites. This project is an attempt to transfer current state-of-the-art technology in the areas of intelligent scheduling and health monitoring to the operation of automated telescopes. It is a collaborative effort between individuals and groups working in telescope design and control, intelligent scheduling, health monitoring and fault diagnosis, and astronomy.

## Progress and results

- Developed a high fidelity Automatic Photometric Telescope (APT) simulator, designed to allow the in-house development and testing of advanced planning and scheduling control software.
- Developed a prototype Interactive Scheduling Tool, which was put to immediate use in preparing the Fall 1991 observing schedule for an operating APT.
- Developed a cooperative control system which makes use of optimum schedules when available from the scheduler, but without entirely abandoning the default heuristic technique.

- Benchmarked the performance increase in the use of new scheduling algorithms in existing simulated control systems.
- Held a workshop on the application of a prototype autonomous telescope to a Lunar precursor mission.
- Formed a group of automatic telescope users from around the United States dedicated to implementing and testing distributed network control concepts.

## Significance of the results

Automated science instruments, such as astronomical telescopes, are likely to revolutionize the way in which modern observational science is performed. The cost effectiveness and performance increases possible with automatic (as opposed to manual) operation of science instruments means that more scarce resources can be devoted to acquiring the science data rather than supporting the infrastructure. This is especially true with space-based instruments because infrastructure costs are a significant fraction of the total costs of a mission. This work has shown that the application of artificial intelligence techniques, such as advanced scheduling, can increase the performance and flexibility of automated telescopes. In addition to the simple quantitative increase in the performance of the system, there is a qualitative increase in the capabilities of the system. This is especially true when these techniques are applied to complex networks of science instruments. A cooperating network of astronomical telescopes, differing in either wavelength sensitivity or in geographical location, can perform a new type of observational science difficult or impossible to do with classical telescopes and observing techniques.

## Future plans

1993: Apply scheduling algorithms to field use and measure their performance. Acquire an automatic telescope locally for fault diagnosis and health monitoring research.

1994 and beyond: Implement an Antarctic-based robotic telescope as a Lunar mission precursor.

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2. The APT Planning and Scheduling Manifesto, M. Drummond, J. Bresina, K. Swanson, A. Philips, and R. Levinson, 1991 NASA ARC Technical Report #FIA-91-24.
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4. An Application of Artificial Intelligence to Automated Telescopes, K. Swanson, M. Drummond, and J. Bresina, Proceedings of the Remote Observing Workshop, Tucson, AZ, April 1992.
5. Proceedings of the Steerable Automatic Luna Ultraviolet Telescope Explorer (SALUTE) Workshop, NASA Ames Research Center, May 1992, B. Hine (ed).
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**References:** None so far

# Controlling Lifetimes and Reaction Dynamics of High Energy Density Materials by Modifying Chemical Environments

## Investigator(s)

Winifred M. Huo, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Timothy L. Lee, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

High energy density materials (HEDM) are generally metastable, causing significant problems in their storage and transportation. Many potential candidates for high energy fuels are eliminated due to their instability. This project investigates how the chemical environment can be modified to stabilize potential HEDM candidates so their energy may be harvested for propulsion. Fluorine azide ( $\text{FN}_3$ ) is used as a prototype molecule to illustrate the general principle.

$\text{FN}_3$  belongs to the class of HEDM candidates which are chemically bound excited states. Its energy content is above that of the dissociation products  $\text{N}_2 + \text{NF}$ . Thus it would decompose spontaneously except for the existence of a 14 kcal/mole barrier. The energy released from its decomposition, 65 kcal/mole, is a potential source of propulsion. Also, the lowest energy state of bound  $\text{FN}_3$  is a singlet, whereas the total spin of the dissociation products is a triplet. The instability of  $\text{FN}_3$  is a result of a crossing between the singlet and triplet potential energy surfaces.

Experiments by Benard et al. (ref. 1) at Rockwell International suggest that the decomposition will be slow and the molecule is relatively stable if the crossing of the two surfaces occurs after the transition barrier of the singlet surface. This is the case for gas phase  $\text{FN}_3$ . By contrast, if the crossing occurs before the dissociation barrier, the molecule tends to decompose via the highly repulsive triplet surface, and the rapid dissociation generates a detonation wave. The latter mechanism is the source of the explosive nature of  $\text{FN}_3$  in the condensed phase.

This study employs quantum chemical methods to calculate the crossing of the lowest singlet ( $^1A'$ ) and triplet ( $^3A''$ ) surfaces of  $\text{FN}_3$ . The calculation of an isolated  $\text{FN}_3$  molecule was used to investigate its dissociation pathway in the gas phase. Calculations of  $\text{FN}_3$  in a cluster with one or more other molecules

were used to simulate its behavior in the condensed phase and to investigate the effect of its chemical environment on the dissociation pathway.

Calculations were also carried out to determine the geometry and vibrational frequencies of  $\text{FN}_3$  at equilibrium and at the top of the barrier, using SCF and CASSCF methods. Equilibrium geometry was also determined using CCSD and CCSD(T) methods.

## Progress and results

For an isolated  $\text{FN}_3$ , the crossing occurs after the barrier (fig. 1), in agreement with experiment. For the cluster  $\text{FN}_3\text{-O}_2$  (fig. 2), the crossing also occurs after the barrier, but for  $\text{FN}_3\text{-N}_2$  (fig. 3) and  $\text{FN}_3\text{-(H}_2)_3$  (fig. 4), the crossing shifts to the left-hand side of the barrier. Table 1 presents the computed frequencies at both the equilibrium geometry and at the top of the barrier using the CASSCF method. Experiment data of vibrational frequencies at equilibrium geometry are also given.

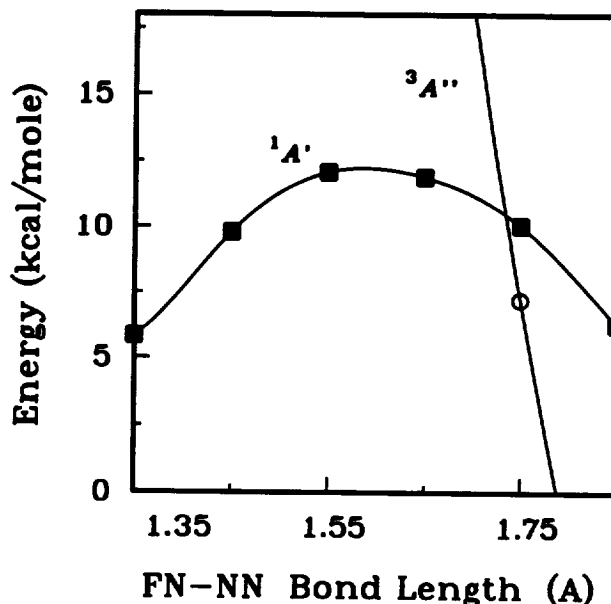


Figure 1.  $\text{FN}_3$ .



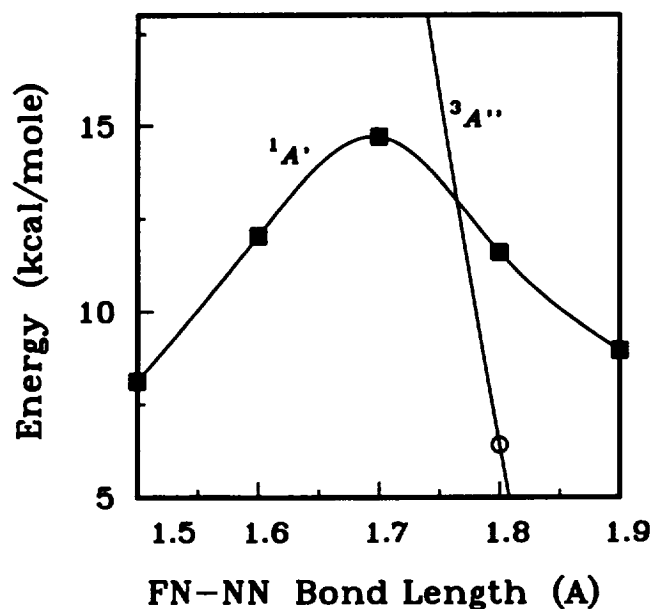


Figure 2.  $\text{FN}_3\text{-O}_2$ .

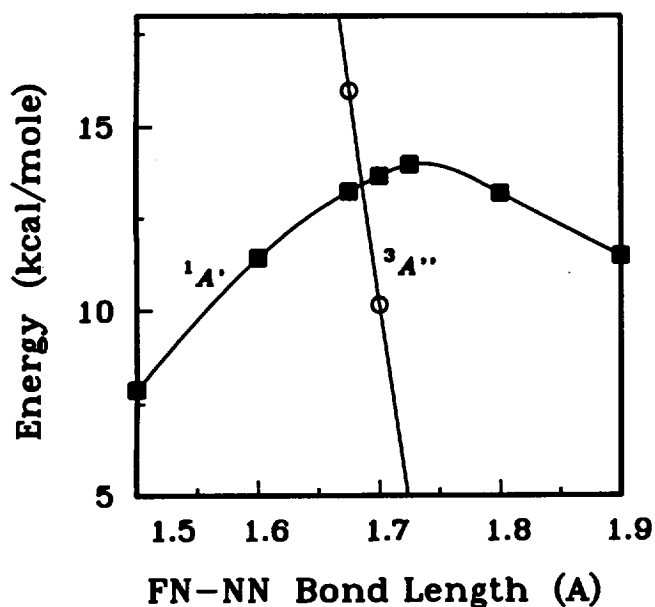


Figure 3.  $\text{FN}_3\text{-N}_2$ .

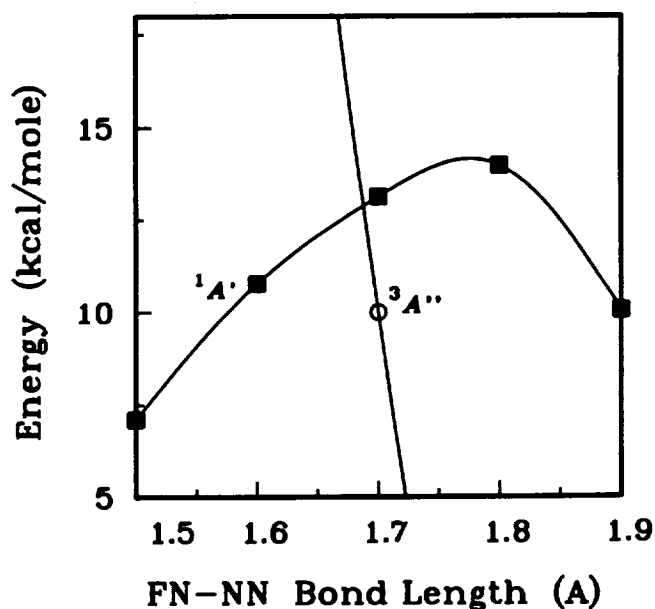


Figure 4.  $\text{FN}_3\text{-(H}_2\text{)}_3$ .

Table 1. Vibrational frequencies of  $\text{FN}_3$  at equilibrium geometry and at the top of the barrier.

Mode	Equilibrium		Top of barrier
	CASSCF	Expt (ref. 2)	CASSCF
$\nu_1$	2118.8 $\text{cm}^{-1}$	2037	2325.6
$\nu_2$	1022.0	1090	920.4
$\nu_3$	826.9	873.5	410.6
$\nu_4$	641.2	658	136.1
$\nu_5$	248.1	243	dissoc.
$\nu_6$	513.7	504	198.8

### Significance of the results

The validity of our theoretical approach is demonstrated by the agreement between the dissociation pathway deduced from figure 1 and the experimentally deduced dissociation pathway (ref. 1) for gas phase  $\text{FN}_3$ . Our results for  $\text{FN}_3$  clusters show that  $\text{FN}_3$  will dissociate very rapidly in the presence of  $\text{N}_2$  and/or  $\text{H}_2$  because its ground state surface crosses the excited state surface before the dissociation barrier. Thus  $\text{FN}_3$  is unstable if it is stored in liquid  $\text{N}_2$  or  $\text{H}_2$ . On the other hand,  $\text{FN}_3$  should be relatively stable if stored in liquid  $\text{O}_2$  because, in the presence of  $\text{O}_2$ , the two surfaces cross after the barrier.

This study demonstrates that materials may be produced which have high energy densities as well as stability. More specifically, the present results indicate that it is possible to store  $\text{FN}_3$  in liquid  $\text{O}_2$  and generate a highly energetic but relatively stable oxidizer.

**Publications resulting from study:** None so far

## References

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# Real Time Automated Diagnosis System for an Animal Holding Facility

## Investigator(s)

David L. Iverson and Stephanie Herrin,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

Formal reliability analyses, such as fault tree, digraph, or FMEA analyses, are performed on many engineered systems. These analyses contain a wealth of information that could be used to help build automated diagnostic systems. A significant amount of effort could be saved by using reliability analysis information to build a diagnostic system since much of the knowledge engineering required for such a system will be done by the system engineers while performing the reliability analysis. However, appropriate knowledge representations and reasoning techniques that take full advantage of the information contained in these reliability models have not been developed.

One system which could benefit from research in this area is the Ames Research Animal Holding Facility (RAHF). The RAHF is a Spacelab module designed at Ames that is used to house and monitor animals in orbit so the effects of space flight and microgravity can be studied. A detailed matrix FMEA reliability analysis has been performed on the RAHF. With further research into the use of reliability analyses for automated diagnosis, the information contained in the RAHF analysis can be put to work for RAHF payload support personnel by developing an automated system to help them detect, identify, diagnose, and repair problems that may occur in the RAHF system.

The objectives of this study are to improve knowledge engineering and automated diagnosis technology by developing general techniques for constructing automated diagnostic systems using information from reliability analysis models. The techniques we develop will be tested in a proof-of-concept monitoring and diagnosis system for the RAHF. We plan to deploy a system prototype to assist in payload operations during the flight of the RAHF on the SLS-2 mission in August 1993.

## Progress and results

In our first year of research we have devised a systematic method for converting matrix FMEA reliability models into diagnostic knowledge bases. A knowledge representation for those knowledge bases has been developed. We have built an RAHF diagnostic knowledge base for use with the Fault Tree Diagnosis System (FTDS) currently under development in the Spacecraft Data Systems Research Branch at Ames. This knowledge base was constructed in a modular fashion so it can be updated for use when different animal enclosures are used in the RAHF. FTDS will be augmented to provide recovery advice for any diagnosed failures using existing corrective action checklists and information from RAHF system experts and the RAHF FMEA analysis.

We have also begun work on a monitoring system to detect anomalies in the RAHF telemetry. Methods for integrating the telemetry monitor with the diagnosis system are under development. In addition, a prototype graphical display to present RAHF telemetry data has been designed and tested with RAHF telemetry from the SLS-1 mission. All of these elements will be combined to produce our automated monitoring and diagnosis system prototype.

## Significance of the results

The research has produced general techniques for using traditional reliability models for automated diagnosis. Using these techniques, an automated monitoring and diagnosis system can be produced for any system which undergoes a matrix FMEA analysis. This could save a great deal of time and expense that would otherwise be devoted to knowledge acquisition and knowledge engineering activities. Our studies have also provided insight on how reliability analysts can modify their analyses to further facilitate diagnostic reasoning.

**Publications resulting from study:** None so far

**References:** None so far

# Stratospheric Aerosol Particulates: Simulation of Their Morphology, Physical Properties, and Chemistry

## Investigator

Richard L. Jaffe, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

It is believed that nitric acid-water aerosols play an important role in the chemistry of the stratosphere that is responsible for the formation of the so-called ozone hole at the polar latitudes during the early spring. The aerosol mechanism involves the conversion of chemically inactive forms of chlorine (such as HCl) to active forms (Cl<sub>2</sub> and HOCl) on the surfaces of micron-sized nitric acid-water droplets which comprise the polar stratospheric clouds. The properties and chemistry of these aerosols are not well understood. Laboratory measurements have generally not accurately reproduced the ambient conditions and *in situ* measurements are difficult.

A new approach for studying the morphology and properties of nitric acid-water aerosols is to use molecular simulation techniques. First the nature of the interaction between nitric acid and water molecules is deduced from *ab initio* quantum chemical calculations of the interaction potential. Then atomistic classical mechanics simulations of ensembles of nitric acid and water molecules will be carried out. Both the bulk and surface structures of a collection of these molecules will be ascertained.

Finally, simulations of collisions between HCl molecules and the aerosol surface will be carried out to study the gas-surface kinetics. From these calculations, the sticking coefficient can be determined.

## Progress and results

This project was started in February 1992. To date the interaction potential between nitric acid and water molecules has been determined. We find evidence for strong hydrogen-bonded complex as well as ionic complexes. The latter have been investigated with up to three pendant water molecules (H<sub>9</sub>O<sub>4</sub><sup>+</sup>·NO<sub>3</sub><sup>-</sup>). The isolated hydrogen-bonded complexes (H<sub>2</sub>O···HNO<sub>3</sub>) are lower in energy than the isolated ionic ones. Therefore the preference for ionic complexes in condensed phase must arise from longer-range lattice effects. These are treated in the simulations using Ewald summations over the partial atomic charges. The structures and vibrational spectra of the individual complexes are in good agreement with laboratory studies on thin films of nitric acid-water mixtures.

**Significance of the results:** None so far

**Publications resulting from study:** None so far

**References:** None so far

# Use of Molecular Fossils to Interpret Paleoenvironments

## Investigator(s)

Linda L. Jahnke, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Tsegereda Embaye, San Jose State University,  
San Jose, CA

## Objectives of the study

The most important biological influence on the evolution of this planet was the development of oxygenic photosynthesis. This process, which evolved within a group of photosynthetic bacteria, transformed Earth's atmosphere from an anaerobic to an oxygen-rich one. However, clear paleobiological evidence of the timing of this transition, and the biochemical evolution that led to it, is lacking. Recent technical advances in the microanalysis of organic matter have made it possible to detect residual molecules (biomarkers) in proterozoic (2.5 to 0.6 billion years) sedimentary rock characteristic of specific groups of microorganisms. Biomarker analysis is proving to be a powerful tool for decoding the record of ancient biochemistry found in the geological record; however, further information about the biomarkers of photosynthetic organisms is necessary to fully interpret information about the evolution of oxygenic photosynthesis present in sedimentary rocks.

Two types of photosynthesis are carried out by bacteria: anoxygenic and oxygenic. Anoxygenic photosynthesis is more primitive, and involves conversion of a reduced compound such as hydrogen sulfide to elemental sulfur or sulfate. With oxygenic photosynthesis, the evolution of a more complex electron transport system allows conversion of water to molecular oxygen. While all cyanobacteria can grow by oxygenic photosynthesis, some are also able to grow by anoxygenic photosynthesis; they are referred to as facultative cyanobacteria. Facultative cyanobacteria are thought to be an evolutionary model for the development of oxygen-evolving photosynthesis from the more primitive anoxygenic types.

This study addresses the need to more fully understand the synthesis of a type of biomarker molecule (the hopanoids) in photosynthetic bacteria and any relationship that the presence of these biomarker molecules might have to the evolution of oxygenic photosynthesis.

## Progress and results

Initial work has involved the growth of several types of photosynthetic bacteria and development of methods for the isolation and identification of any hopanoid molecules present in these organisms. Two marine, purple photosynthetic bacteria (anoxygenic types) have been grown, their hopanoids isolated, and the molecular structures verified by gas chromatography-mass spectrometry. Both *Rhodospirillum salexigens* and *Rhodobacter sulfidophilus* contain high levels of a C32-type hopanoid (fig. 1). Work has also begun with several cyanobacteria, *Oscillatoria amphigranulata* and a newly isolated *Phormidium* sp. We have found that like *O. amphigranulata*, this *Phormidium* is capable of photosynthetic conversion of carbon dioxide to cell material using either water (oxygenic) or hydrogen sulfide (anoxygenic) as the electron donor.

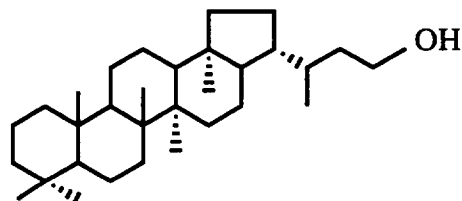


Figure 1. Structure of the C32 hopanoid isolated from marine purple photosynthetic bacteria.

## Significance of the results

Marine ecosystems have played a major role in deposition of organic matter both in the present and in the Proterozoic. The characterization of C32 hopanoids in *Rsp. salexigens* and *Rb. sulfidophilus* provides evidence for the source of this type of hopanoid in marine environments. In the case of *Rb. sulfidophilus*, growth of this organism under anaerobic, highly reduced conditions, corroborates the theory that oxygen is not required for synthesis of this molecule and that the presence of hopanoids in sedimentary organic matter should not be equated with the presence of oxygen-utilizing organisms.

**Publications resulting from study:** None so far

**References:** None so far

# Pyrosensors for Detecting Chemical Compounds in Planetary Environments

## Investigator(s)

Daniel R. Kojiro and Thomas C. Shen,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

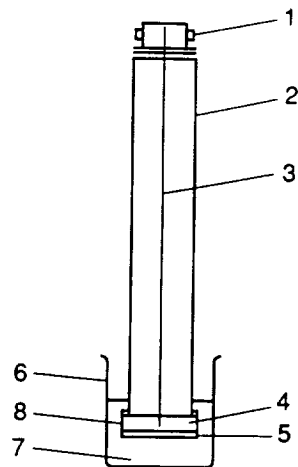
One of the most important discoveries of the Viking Mission to Mars was the unusual chemical activity of Martian soil during the biology experiments. Oxygen gas rapidly evolved from samples when it was exposed to water or humidified (Gas exchange experiment) and nutrients that were added to the soil were oxidized to carbon dioxide gas (Gas exchange and Labeled release experiments) (ref. 1). When samples were heated at temperatures of 145-165 °C, the evolution of carbon dioxide gas was observed (Labeled release experiment), but oxygen gas still came off upon humidification (Gas exchange experiment). These results in particular can be better explained by the presence of a nonbiological oxidant such as peroxide or superoxides in the soil (refs. 1,2).

One major difference between soil on Earth and Mars is that Martian soils, at least at the Viking landing sites, are never apparently exposed to water in the liquid state: the water occurs only as gas, low temperature adsorbate, frost, and ice; and this might have produced some of the activity (ref. 2). Several experiments have been designed by different groups to study possible models of oxidant formation on Mars (refs. 1-4). The suggested explanations, and many of the experiments, make it likely that peroxides, superoxides, and adsorbed OH are all present. The next step will be determination of oxidant concentration on the Martian surface as well as in different depths under the surface. Our objectives are to develop pyrosensors for determination of the oxidant concentration on the Martian soils.

## Progress and results

The first sensor-1 (fig. 1) provided a very stable baseline, but it was not very sensitive. The hydrogen peroxide concentration can be determined from 40 ppm to 300 ppm with a reasonable calibration curve (as shown in fig. 2) and their chromatograms are shown in figure 3.

In order to increase the sensitivity of the sensor-1, several sensor designs were constructed. Some sensors did increase sensitivity 1000 times compared to sensor



- |                           |                        |
|---------------------------|------------------------|
| 1. BNC connector          | 5. Sensor              |
| 2. Stainless steel tubing | 6. Beaker              |
| 3. Wire                   | 7. Solution            |
| 4. Support                | 8. Stainless steel cap |

Figure 1. Sensor-1 design.

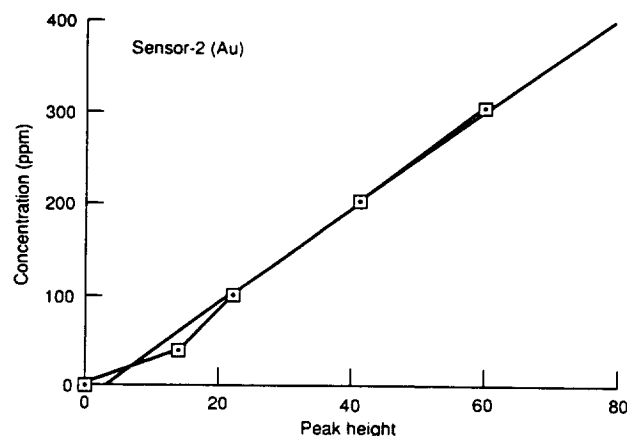


Figure 2. Hydrogen peroxide test (preliminary result).

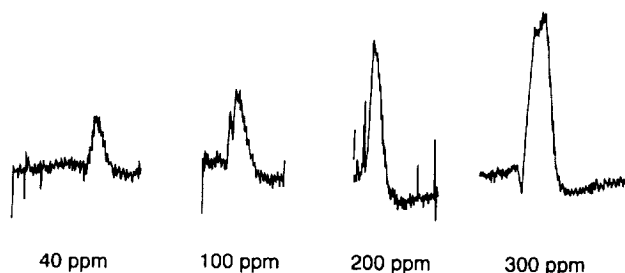


Figure 3. Chromatogram of hydrogen peroxide test results.

design-1 (fig. 1). When hydrogen peroxide was tested in these sensors, the piezo effect was induced by the pressure of a drop of the reagent being added into the test solution. To separate the piezo effect from heat of reaction, an acrylamide solution replaced the hydro-sulfite solution and a high concentration of hydrogen peroxide (25%) was used. The result is shown in figure 4. The low concentration of hydrogen peroxide (5 ppm) was not detected due to oxygen interference.

Recently, two new sensors were constructed to eliminate the piezo effect, but they failed due to technique and material selection problems. We felt that these two sensors should be able to eliminate the piezo effect and allow us to measure the heat of reaction at  $10^{-11}$  °C change. Future experiments will include using new sensor materials sensitive only to heat which will not have a piezo effect, and directly joining the PVDF (polyvinyliden fluoride) sensor on a chip (MSFET) to miniaturize the design.

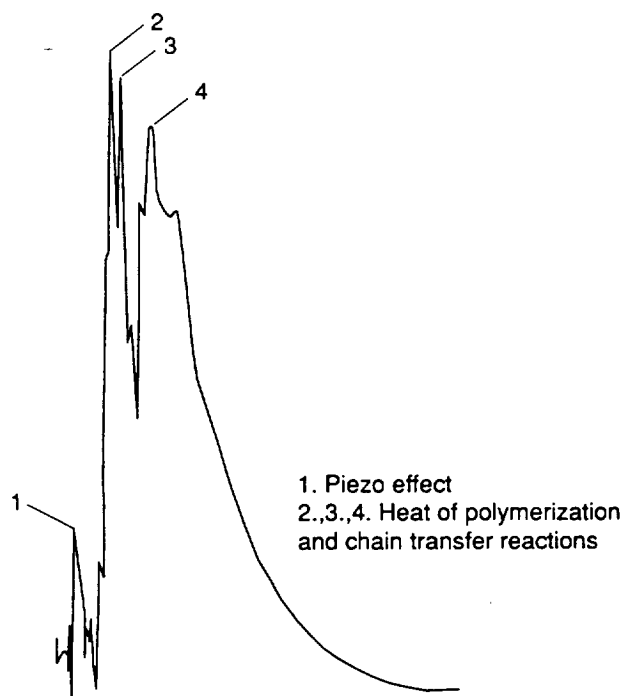


Figure 4. Heat of acrylamide polymerization.

### Significance of the results

The preliminary results indicate that the pyrosensor can be used to determine the heat of reaction and thus, the concentration of hydrogen peroxide at 40 to 300 ppm. In order to be able to determine lower concentrations of hydrogen peroxide, new sensor designs and new pyro materials will be investigated.

**Publications resulting from study:** None so far

### References

1. Klein, H. P.: Icarus, vol. 34, 1978, pp. 666-674.
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4. Oyama, V. I.; Lehwalt, M. E.; and Berdahl, B. J.: Presented at the 17th Conference on Space Research (COSPAR), Innsbruck, 1978.

# Study of Ozone Depletion Chemistry Using *Ab Initio* Quantum Mechanical Methods

## Investigator(s)

Timothy J. Lee, Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Julia E. Rice, IBM Almaden Research Center,  
San Jose, CA  
Celeste M. Rohlfing, Sandia National Laboratory,  
Livermore, CA

## Objectives of the study

Extensive documentation of the destruction of the ozone layer, especially over the Antarctic, has been obtained over the past 15 years. A great deal has been learned about the mechanisms involved in the formation of the Antarctic ozone hole, and yet there remains considerable chemistry of chlorine, fluorine, bromine, and nitrogen oxides that is not understood. Up to this point, *ab initio* quantum chemistry has contributed little to the understanding of atmospheric chemistry. To a large extent, this is because low-level *ab initio* quantum mechanical methods are not very reliable for molecules that contain several electronegative atoms bonded together. However, in the last 5-8 years considerable progress has been made in the development of highly accurate, moderately inexpensive methods.

The objectives of this study are twofold. First, we wish to study the chemical reactions involved in ozone depletion, with special emphasis on the chemistry that takes place in the Antarctic ozone hole. Initially, chlorine oxides of chemical formula  $\text{Cl}_2\text{O}_2$  and  $\text{Cl}_2\text{O}_3$  have been targeted. A high level *ab initio* study of  $\text{Cl}_2\text{O}_2$  is of interest for two reasons, namely that ClO dimer is thought to be the major reservoir of Cl in the ozone hole during the "nighttime," and also because there is some reliable experimental data available for at least two isomers of  $\text{Cl}_2\text{O}_2$ . Comparison to the reliable experimental data will allow the theoretical methods to be assessed and the calculations will provide information on other molecular properties that is not available from experiment. In addition, recently there has been considerable interest in the protonation reaction of chloronitrate ( $\text{ClONO}_2$ ) as a possible mechanism for elimination of  $\text{ClONO}_2$  by heterogeneous reaction on the surfaces of polar stratospheric clouds (PSCs).



Since we have previously studied the protonation reactions of  $\text{HONO}_2$  and  $\text{CH}_3\text{ONO}_2$ , the results of which suggest the importance of reaction (1), we have also begun a study of the thermochemistry of reaction (1).

The second objective of this study is to demonstrate that the newly developed high-level *ab initio* methods are capable of yielding very accurate results for molecules composed of several electronegative atoms bonded together, and therefore are capable of providing important understanding and data in the study of atmospheric chemistry.

## Progress and results

A high-level study of the equilibrium structures, vibrational frequencies, quadratic force fields, and thermochemistry of the three lowest-lying isomers of  $\text{Cl}_2\text{O}_2$  has been completed and accepted for publication in the Journal of Chemical Physics (see Publications section). This study showed that the CCSD(T) *ab initio* method provides highly accurate results by comparison to experiment for the structures and vibrational frequencies of  $\text{ClOOCl}$  and  $\text{ClClO}_2$ , the two lowest isomers of  $\text{Cl}_2\text{O}_2$ . In addition, an experimental assignment of one of the vibrational bands of  $\text{ClOOCl}$  was corrected using the *ab initio* data. The binding energy of  $\text{ClOOCl}$ , relative to dissociation to  $2\text{ClO}$ , was confirmed using the *ab initio* results. In the process, it was shown that the heat of formation of  $\text{Cl}_2\text{O}$  given in the JANAF tables is too large by  $\approx 1.5$  kcal/mol.

We have also completed a study of the structures, vibrational spectra, quadratic force fields, and thermochemistry of  $\text{FNO}_2$  and trans- and cis-FONO (this has appeared in the Journal of Chemical Physics). There has been considerable controversy recently concerning the equilibrium geometry of cis-FONO. One interpretation of matrix isolation experiments suggested that the F-O bond distance was very long, or in other words that cis-FONO was effectively a weakly bound complex between the fluorine and ONO radicals. A density functional calculation supported this interpretation. However, our CCSD(T) calculations showed beyond any doubt that cis-FONO adopts a structure more similar to cis-HONO; i.e., a normal F-O single bond distance is obtained. Further, vibrational frequencies determined with the CCSD(T) method showed how a misinterpretation of the matrix isolation experiments led to the erroneous structure.



According to *Chemical Kinetics and Photochemical Data for Use in Stratospheric Modeling*, Evaluation numbers 9 and 10 (JPL Publication 92-20),  $\text{FNO}_2$  and FONO are formed in the atmosphere by reaction of fluorine and ONO radicals. Our study showed that  $\text{FNO}_2$  is considerably more stable than cis-FONO (which is more stable than trans-FONO). However, the ultimate importance of cis-FONO in atmospheric chemistry will depend on the potential barrier separating cis-FONO and  $\text{FNO}_2$ , since the formation of cis-FONO is kinetically favored. A second study concerning this aspect has been started.

As indicated previously, we have also initiated studies aimed at (1) determining the structure and vibrational spectrum of the lowest-lying isomers of  $\text{Cl}_2\text{O}_3$ , and (2) determining the thermochemistry of reaction (1) in order to assess the importance of this reaction in depletion of  $\text{ClONO}_2$  in the chemically perturbed region of the Antarctic ozone hole. These studies are about 50% and 75% completed, respectively.

### Significance of the results

As  $\text{ClOOC}\text{Cl}$  is a very important constituent of the ozone hole, it is imperative that the properties of this molecule be well understood. We have shown that some of the previously accepted experimental data for this system is incorrect, while we have also confirmed the rather large binding energy (with respect to dissociation to  $2\text{ClO}$ ) that  $\text{ClOOC}\text{Cl}$  possesses. An accurate binding energy is important so that reliable thermal dissociation rates may be calculated. In this study, the energy difference between  $\text{ClOOC}\text{Cl}$  and  $\text{ClClO}_2$  was also shown, unequivocally, to be very small. The ultimate importance of the  $\text{ClClO}_2$  isomer in atmospheric chemistry has yet to be determined (clearly,  $\text{ClOOC}\text{Cl}$  is the favored product from reaction of two  $\text{ClO}$  molecules). This is partly because  $\text{ClClO}_2$  has never been identified in the atmosphere. This is because it has only recently been characterized in the laboratory. In addition, we plan to investigate the potential barrier

separating  $\text{ClOOC}\text{Cl}$  and  $\text{ClClO}_2$ , which will also reflect the importance of  $\text{ClClO}_2$ . It is important to determine exactly which chlorine oxides are present in the ozone hole, as the different compounds will have different photodissociation products and thus different rates and mechanisms of ozone destruction.

Our study of cis-FONO has shown beyond doubt that the interpretation of the experimental matrix isolation experiments was flawed. The structure of cis-FONO is much as would be expected based on similar compounds, and is not atypical. However, cis-FONO is considerably higher in energy than  $\text{FNO}_2$  ( $36.9 \pm 2.5$  kcal/mol at 0 K). So its ultimate importance in atmospheric chemistry will be determined by how readily cis-FONO rearranges to  $\text{FNO}_2$ . This is because the formation of cis-FONO from fluorine and ONO radicals is kinetically favored over the formation of  $\text{FNO}_2$ .

Perhaps the most significant result to appear from these studies is the fact that *ab initio* quantum mechanical methods have clearly been shown to yield very accurate structures, vibrational spectra, and thermodynamic information for molecules composed of several electronegative atoms—that type of molecule which is most prevalent in the upper atmosphere. The results thus far demonstrate that the study of atmospheric chemistry, through the use of quantum mechanical methods, is very informative and a useful complement to experimental studies.

### Publications resulting from study

1. Lee, T. J.; and Rice, J. E.: FONO: A Difficult Case for Theory and Experiment, *J. Chem. Phys.*, vol. 97, 1992, p. 4223.
2. Lee, T. J.; Rohlfing, C. M.; and Rice, J. E.: An Extensive Ab Initio Study of the Structures, Vibrational Spectra, Quadratic Force Fields and Relative Energetics of Three Isomers of  $\text{Cl}_2\text{O}_2$ , *J. Chem. Phys.*, in press.

**References:** None so far

# Search for Interstellar Molecules in Carbonaceous Meteorites

## Investigator(s)

Narcinda R. Lerner and Sherwood Chang,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Etta Peterson, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

Many classes of organic compounds exist in carbonaceous meteorites. Their origins are poorly understood. These compounds could have originated in the solar nebula, the parent body, or the interstellar medium.

The criterion for origin in the interstellar medium is anomalous D/H ratios. Anomalous D/H ratios have been observed in amino acids, carboxylic acids, and kerogenous stuff obtained from carbonaceous meteorites. To date, all measurements of isotope ratios have been made at the compound class level; there is no data at the compound level. Such data are needed in order to develop a mechanism for the formation of these compounds.

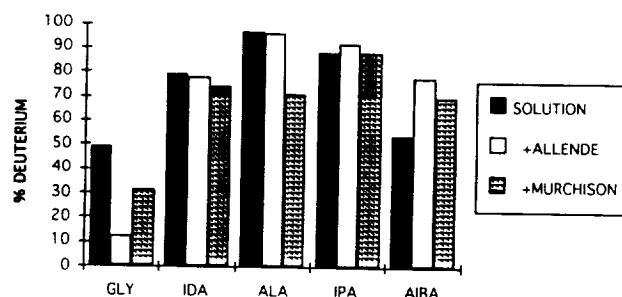
Mechanisms for the formation of compounds can be inferred from D/H ratios measured in meteoritic organic compounds by comparing deuterium hydrogen exchange in laboratory simulation of postulated synthetic routes to compound formation. The overall objective of this project is to obtain data that will reveal the D/H distribution in organic compounds found on meteorites as a function of molecular structure and to relate the D/H ratios to possible synthetic pathways originating with deuterium enriched molecules formed in the interstellar medium.

During this period the Strecker synthesis,  $RR'CO + NH_3 + HCN + H_2O \rightarrow RR'C(NH_2)CO_2H$  was investigated as a possible source of the deuterium enriched amino acids found on Murchison from interstellar aldehydes and ketones. The carbonyl compounds used in this synthesis were: formaldehyde ( $R = R' = D$ ) expected to yield glycine (GLY), acetaldehyde ( $R = D, R' = CD_3$ ) expected to yield alanine

(ALA), and acetone ( $R = R' = CD_3$ ) expected to yield  $\alpha$ -amino isobutyric acid (AIBA).

## Progress and results

The Strecker synthesis has been carried out in aqueous solution ( $H_2O$ ) and in aqueous solution containing dust from the Allende meteorites, and dust from the Murchison meteorites. The major products obtained in the Strecker synthesis were the expected compounds ALA, GLY and AIBA. Unexpected products obtained were the imino di carboxylic acids: imino di acetic acid (IDA) and imino acetic propionic acid (IPA). The deuterium retention of these compounds is shown in the figure.



*Deuterium retention during the Strecker synthesis.*

## Significance of the results

The deuterium retention during the Strecker synthesis is sufficiently high that these results could be used in conjunction with the measured D/H ratios of amino acids on meteorites to set limits on the D/H ratios of the putative interstellar precursors. However the imino di acids have not been observed on meteorites. If the Strecker synthesis is the route for amino acids on meteorites, the explanation must be the absence of the imino di acids.

**Publications resulting from study:** None so far

**References:** None so far

# Investigations of Supersonic Combustion Using Unique NASA Ames Facilities

## Investigator(s)

Gene Menees, Ames Research Center,  
Moffett Field, CA 94035-1000  
Jean-Luc Cambier and Henry Adelman,  
Eloret Institute, Palo Alto, CA

## Objectives of the study

This work aims at demonstrating how some unique Ames experimental facilities, combined with new, state-of-the-art computational capabilities, can be used to investigate some key problems in supersonic combustion and hypersonic propulsion. The approach is therefore composed of several components. An array of codes will be used and/or developed to help analyze various aspects of the flow. Notably a new code for the simulation of nonequilibrium arc-jet flows will be developed and validated. The code will be used in particular for predicting the flow features in the direct-connect arc-jet facility (DCAF) to correctly estimate the contamination and nonequilibrium effects during the flow expansion. It will also be coupled to an existing radiation code, which analyzes the molecular and atomic emission and absorption features, along a line of sight. This will allow us to examine the potential of various non-intrusive diagnostic methods. The proposed work also includes conceptual studies of propulsion experiments to be conducted in the DCAF. These proposed experiments will aim at answering some key questions in supersonic mixing and combustion, and will investigate new propulsive concepts. Engineering analyses, experiment design, test plan and preliminary cost estimates will be performed.

## Progress and results

The first objective was to obtain an accurate, reliable CFD capability for the simulation of arc-jet flows. Preliminary analysis of existing codes showed important deficiencies in the capabilities, the numerical methods, or the modeling assumptions. For example, existing codes assume the same value of temperature for vibrational and electronic excitation modes, equal to the temperature of free electrons. This is not necessarily the case, and the validity of this assumption depends on the density of free electrons. Additionally, there is no accounting for radiative recombinations and the energy loss through volumetric emission.

Finally, we need to develop a code with the capability to model all aspects of the arc-jet flow, including the high-temperature arc region. We can then interface with a combustion code for the modeling of the experiment itself. Therefore, new codes have been written to accurately model all aspects of the arc-jet flow. The principal component is an extension of the combustion code *Mozart*, previously used for the simulation of detonations, pulsed combustion, shock tube and shock tunnel flows, fuel injection, shock transients in nozzles, and re-entry flows. The multi-temperature version can therefore easily be interfaced with the combustion code: the non-equilibrium model assumes 4 different temperatures ( $T_{tr}$ ,  $T_{rot}$ ,  $T_{vib}$ ,  $T_{el}$ ). The excited electronic states and free electrons are assumed to be at the same temperature, a reasonable assumption for most flows. It can, however, differ from the vibrational temperature. This situation can occur when the electron density drops below a critical value and ceases to be an effective coupling medium. The contribution of free electrons to the total pressure is also taken into account. The code can therefore be used to model plasmas with a high degree of ionization.

Other codes are being developed to model nonequilibrium plasmas with an even higher degree of accuracy, notably the code *Mahler*, which models each excited state separately, and can account for collisional-radiative nonequilibrium. Another version treats the plasma as a two-fluid and could be used for the simulation of the arc itself. Advances in the development of these codes will be used for the specific purpose of arc-jet flow simulation when possible.

Other progress includes the design of a new type of fuel injector, which aims at maximizing mixing efficiency in supersonic streams. The design of several experiments to take place in the DCAF are also currently under way.

## Significance of the results

The progress made in modeling of nonequilibrium phenomena will allow us to model the complete arc-jet facility with great accuracy, from the arc region to the nozzle expansion and the combustion experiment. This will also allow us to estimate precisely the effects due to thermal and chemical nonequilibrium on hypersonic combustion flows.

**Publications resulting from study**

A publication is expected to be submitted in 1993 for the Aerospace Sciences Meeting.

**References:** None so far

# Mixing, Combustion, and Thrust Enhancement by a Pulsed Detonation Wave Augmentor

## Investigator(s)

Gene Menees, Ames Research Center,  
Moffett Field, CA 94035-1000  
Jean-Luc Cambier and Henry Adelman,  
Elroret Institute, Palo Alto, CA

## Objectives of the study

This study aims at demonstrating the benefits of incorporating a pulsed combustion device into a conventional scramjet engine design for air-breathing flight at hypersonic speeds. This device, which we call the Pulsed Detonation Wave Augmentor (PDWA) is used at high speeds to stimulate the mixing and combustion in the scramjet combustor by using the interaction between unsteady blast waves and the mixing field. This interaction is known to result in the formation of strong vortices, which can enhance the mixing rate between fuel and air. A strong shock generated by the detonation will also locally raise the temperature and shorten the ignition delay. Additionally, the detonation products contain a significant amount of the chain branching radical OH, which can also stimulate the combustion. The PDWA can also operate at low speeds as a stand-alone air-breathing propulsion device, or in a rocket mode for the final phase of orbit insertion. The extreme flexibility of the device, combined with the low weight and simple design make it an ideal candidate engine for a single stage to orbit (SSTO) vehicle. This study attempts to demonstrate the feasibility of operating the PDWA device in all these regimes.

## Progress and results

Our first priority was to examine the effect of the interaction between the blast waves generated by the PDWA and the mixing layer in a supersonic combustor. Several design options can be considered; the first one consists of generating blast waves transverse to the main direction of propagation of the detonation front. In this design, the detonation front still provides thrust in the axial direction, while transverse blast waves are expected to modify the structure of the mixing layer and stimulate the formation of vortices at the fuel/air interface. A generic scramjet/PDWA configuration was modeled in real time, for two cases of PDWA pressure. The flow was computed for a single

PDWA cycle only, and attention was focused on the flow in the scramjet combustor.

## Significance of the results

A sequence of calculations is shown in figure 1. The PDWA tube uses two transverse orifices which allow the detonation waves to enter the main combustor flow. A planar mixing layer was established as an initial state in the scramjet combustor. In this case, the PDWA tube was filled with a stoichiometric hydrogen/air mixture at atmospheric pressure, while the pressure in the supersonic combustor is assumed to be 0.5 atm. The peak pressure behind the detonation front reaches 13 atmospheres. It is clear from figure 1 that the high pressure ratio between the detonated products and the scramjet leads to the propagation of very strong blast waves into the scramjet flow. The mixing layer is significantly displaced and heated. It is particularly interesting to notice that a normal shock is momentarily established inside the mixing layer. The corresponding rise in temperature is sufficient to trigger combustion: this can be seen for example in figure 2, showing the contours of the molar fraction of water in that region ( $t = 300 \mu\text{sec}$ ).

The results clearly show a strong interaction between the blast waves and the mixing layer. However, the shocks may also significantly reduce the stagnation pressure of the overall flow, thereby lowering the propulsive efficiency. It would be desirable to have weaker shocks and therefore use a lower pressure in the detonation tube. The same computations carried on for a tube at 0.2 atm (peak pressure 3 atm behind detonation) show a weaker shock structure in the scramjet flow (fig. 3). The wave-layer interaction is also weaker, resulting in less mixing enhancement, and the combustion is not sufficiently stimulated, as can be seen in figure 4, to be compared with figure 2. It is difficult for this design to simultaneously achieve the enhancement of mixing and combustion while keeping the shock losses to a minimum. Several more calculations will be performed to optimize the PDWA pressure for this design. In another design option (axial interaction) which will be studied, there is no bleeding of the detonation wave into transverse blast waves. Instead, the detonation front itself, after exiting the tube end, is allowed to interact with the mixing layers. Both designs are currently being evaluated.

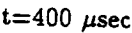
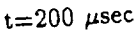
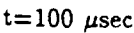


Figure 1. Case 1 ( $P_\infty = 1$  atm in tube),  $\log(\text{density})$  contours.

### Publications resulting from study

Cambier, J. L.; Adelman, H. G.; and Menees, G. P.: Numerical Simulations of a Pulsed Detonation Wave Augmentor Device, abstract submitted to the

AIAA 29th Joint Propulsion Conference, Monterey,  
June 1993.

**References:** None so far

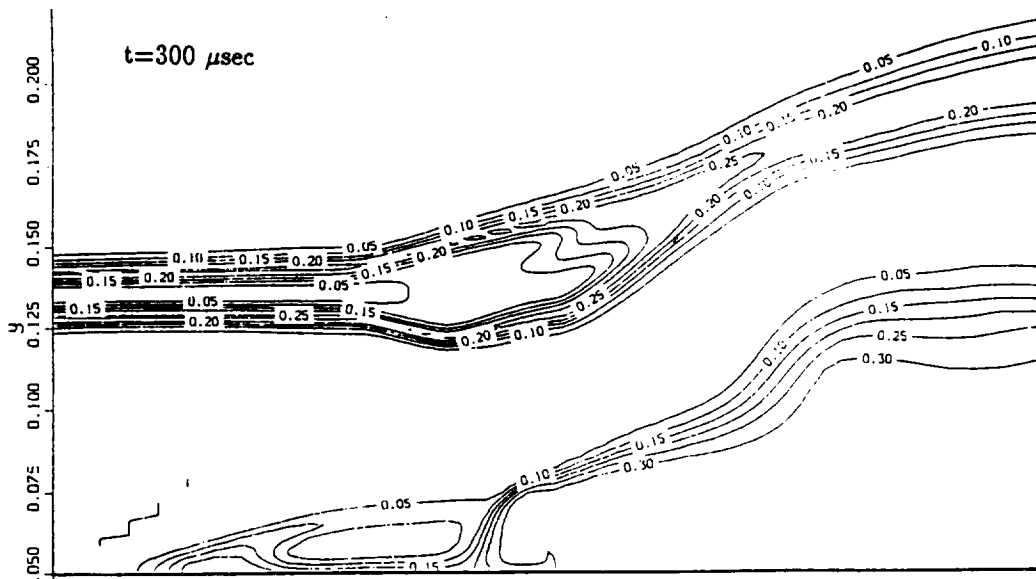


Figure 2. Case 1, water mole fraction contours.

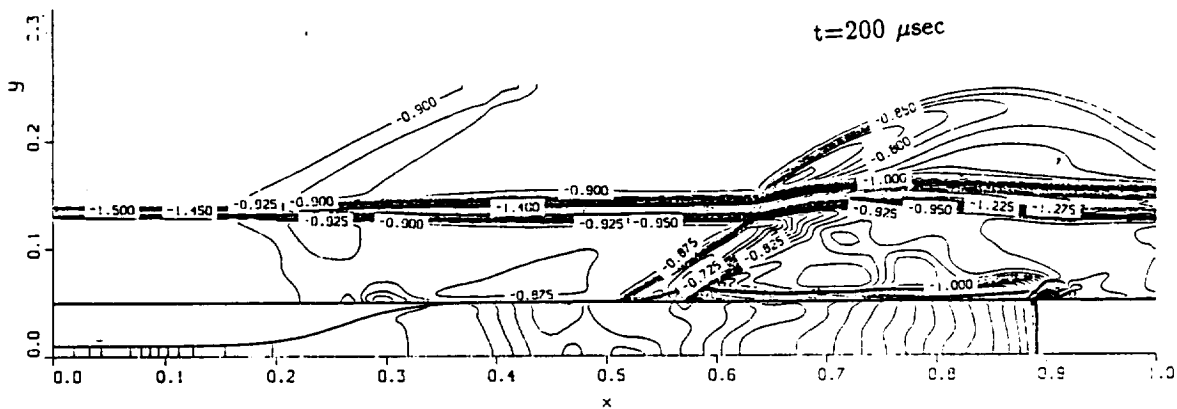


Figure 3. Case 2 ( $P_{\infty} = 0.2$  atm in tube), log(density) contours.

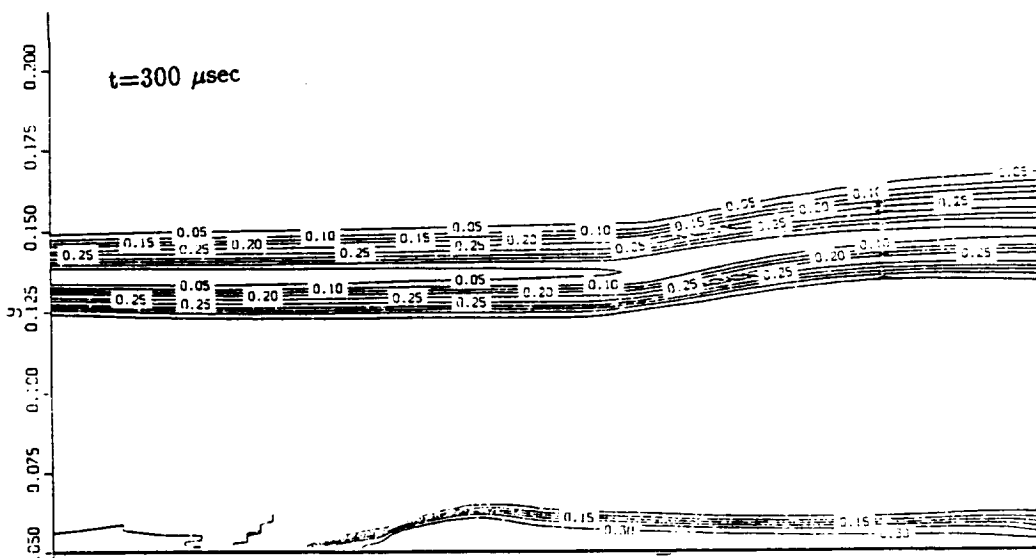


Figure 4. Case 2, water mole fraction contours.

# Ablating Surface Heat Transfer Estimation for Flight Application

## Investigator(s)

Greg Noffz and Mike Bowman,  
Ames Dryden Flight Research Facility,  
Edwards, CA 93523-0273

## Objectives of the study

Flight vehicles can be instrumented with subsurface thermocouples such that inverse analysis procedures can yield useful estimates of surface heat transfer. If the vehicle has an ablating heat shield, however, temperature time histories from subsurface thermocouples no longer provide enough information to estimate heat flux at the surface. This situation arises because the problem geometry is changing and thermal energy is leaving the surface in the form of ablation products. The ablator recession rate is now required to estimate heat transfer to the surface.

This research effort has concentrated on developing a capacitive gage concept in which the ablator has a dielectric effect on the capacitor's fringe region. Relying on a capacitor's fringe region enables the gage to be flush mounted in the vehicle's permanent structure and not intrude into the ablative heat shield applied over it. Our goal is to develop this concept into a gage capable of measuring the recession of low temperature ablators that are applied in thin (0.020 – 0.060-inch) layers. Candidate gage geometries have been evaluated using Delrin shims and Teflon tape layers to simulate the presence of an ablator.

A method of measuring the small changes in capacitance has been tested which involves making the gage part of a series RLC "load" at the end of a waveguide. RF energy is sent to the RLC circuit via the waveguide from a signal generator. If the load is excited at its resonant frequency, all the energy from the source is dissipated in the load's resistance. If the load's resonant frequency now changes (say, due to a change in

capacitance), some of the RF energy will be reflected back toward the source. This reflected energy is detected by a reflection coefficient bridge (RCB) which outputs a DC signal proportional to the amount of mismatch at the load.

## Progress and results

Eight candidate designs have been lab tested using the waveguide/RCB arrangement and Delrin shims to simulate the ablator. Although manufacturing problems (warping and tapering) with the shims have prevented us from obtaining true "Delrin calibrations" for the candidate gages, remarkable consistency between different gages of the same geometry was observed. Gage sensitivity drops off for shims greater than about 0.050-inch. The RCB arrangement gives a large percentage change in mV output for the range of interest and is insensitive to cable/hardware arrangement and local RF energy. Qualitative tests of the gage's sensitivity to temperature gave encouraging results.

## Significance of the results

Although judgment about specific gage designs will be made only after more precise methods of evaluation are executed, results so far indicate that this gage concept has the ability to measure thickness changes in the range and to the resolution required. Hardware power and size requirements do not exceed what would be available on a flight vehicle. Additional applications possibly include measuring the sublimation rate of surface flow-vis chemicals like naphthalene and wing ice detection.

**Publications resulting from study:** None so far

**References:** None so far



# A Miniature, Lightweight Ozone Analyzer for Use on Unmanned Stratospheric Research Aircraft

## Investigator(s)

Richard Pearson, Jr., Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

William D. Gunter, Photon Applications,  
San Jose, CA 95118  
Dana Lynch and Jim Eilers,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

The Stratospheric Ozone (O<sub>3</sub>) Layer is of paramount current interest because human-caused changes may—indeed are—reducing Earth's shield for ultraviolet light. Potential consequences of these changes include increases in skin cancer, damage to our eyes and immune systems, damage to terrestrial animals and plants, changes in climate, and even the possibility of a disruption of the marine organisms at the base of the global food chain. The existence of the major depletions in O<sub>3</sub> are well established in the Antarctic. Very recent developments suggest O<sub>3</sub> reductions will also occur in the Northern Hemisphere.

Stratospheric research is clearly going to use light, unmanned aircraft carrying suites of instruments to obtain much of the *in situ* data needed to resolve the scientific issues regarding the ozone layer at altitudes above the operating ceiling of the ER-2. Satellites alone cannot measure most of the critical molecules needed to resolve the outstanding scientific questions. Ozone measuring instruments will be needed along with a suite of other chemical and meteorological sensors for a long time to come. Perseus, the first of these new platforms, is expected to carry a payload of about 50 kg to an altitude of 24 km. Later aircraft are

expected to reach altitudes of at least 30 km. Even where the technology is relatively well known, it is a major undertaking to miniaturize instruments to the point where 3 to 5 people can fly in a single 50-kg payload.

The purpose of this work is to develop and demonstrate the technology required to build a lightweight, extremely small, low power, continuous measuring *in situ* analyzer for O<sub>3</sub> that will operate at altitudes up to 30 km (about 100,000 ft) on high altitude research aircraft.

## Progress and results

Progress during FY92 occurred in four areas.

1. We developed a detailed design for a novel optical absorption cell for use in photometer.
2. We wrote a patent disclosure for the optical absorption cell design.
3. We developed the design for a complete photometer built around the new absorption cell.
4. We started to design the optics to use in a test facility to be built in FY93.

## Significance of the results

Computer models indicate that the new absorption cell design should enable us to build an instrument that not only is lighter in weight, but has potential performance advantages over existing designs employing multiple-pass cells. We are proceeding with the mechanical design of the cell and procurement of the optical components to demonstrate proof of concept and to validate the model results.

**Publications resulting from study:** None so far

**References:** None so far

# Two-Dimensional Polarimetric Observations of the Galactic Center at 10 Microns

## Investigator(s)

Yvonne Pendleton, Lynne Deutsch, and Tom Roellig, Ames Research Center, Moffett Field, CA 94035-1000

## Objectives of the study

To design and build a polarimeter that will operate with a 10- $\mu\text{m}$  camera to conduct infrared polarimetric imaging studies of the galactic center.

## Progress and results

The polarimeter design selected is that of a room temperature, rotating half waveplate (CdS) and a cryogenically cooled, fixed wiregrid polarizer (Ar:Ge). The polarimeter is housed in a compact steel frame and the half waveplate is rotated by a small (500 HP) motor. A Galil motion controller board is programmed to rotate the half waveplate in 22.5 degree increments. The polarimeter hardware was completed in March 1992. Laboratory testing has begun and will continue throughout the engineering phase of the infrared camera. The infrared camera that the polarimeter was designed to be used with will have its first engineering run on the Mt. Lemmon 60-inch telescope in November 1992. The camera contains a two-dimensional Ar:Si array ( $58 \times 62$ ) and several narrow band filters that allow observations in the 8-13  $\mu\text{m}$  window.

We expect to obtain simple polarimetric measurements early in 1993, which will pave the way for the galactic center mapping scheduled for June 1993 (prior to the galactic center observations, which cannot be

done before the summer due to the coordinates of the galactic center, we plan to observe other regions of interest at 10  $\mu\text{m}$ ). These include regions of star formation and planetary nebulae. Such observations will help us to calibrate the instrument so that the more difficult galactic center observations will have a greater chance of success. A significant amount of laboratory and telescope time must be devoted to the accurate calibration of any polarimeter. We are approximately halfway to our goal of completing lab testing by June 1993.

## Significance of the results

There are very few infrared cameras that operate in the 10- $\mu\text{m}$  region, and even a smaller number that have polarimetric capabilities. We intend to use this instrument to study the center of our galaxy to obtain information about distribution of stars and dust. Through a comparison to 2- $\mu\text{m}$  polarimetry results (previously obtained by us), we will be able to compare the near infrared polarimetric images (which show the scattered light component) to the mid-infrared polarimetric image (which is polarized primarily from dichroic absorption of the electric vectors). Our ultimate goal is to learn more about the unusual phenomena present at the center of the Milky Way, which may prove to be typical of spiral galaxies similar to ours.

**Publications resulting from study:** None so far

**References:** None so far

# Detecting Autotrophic Life on Mars by Surveying for Oxygen

## Investigator(s)

Lynn Rothschild, TGS Technology,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## Other personnel involved

Lori Giver, Indiana University, Bloomington, ID  
Jeff Mulert, Pomona College, Pomona, CA  
Bonnie O'Hara, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

One of NASA's goals is to look for evidence of life elsewhere in the Solar System, and Mars is considered the most promising planet. Because of the hypothesized similarities in the environments of early Earth and early Mars, a Martian biota probably would be based on organic carbon. Furthermore, I have argued that there would be selection pressure to evolve carbon fixation (refs. 1 and 2).

The major byproduct of most types of carbon fixation on Earth is oxygen. It is as a result of photosynthesis, the most widespread type of biological carbon fixation, that Earth became aerobic. The ultimate goal of this project is to map the concentration of oxygen over the surface of Mars in order to understand the subsurface. We expect that such an experiment would generate data that would be useful for Mars exploration in several respects.

Locations with relatively higher levels of oxygen may be indicative of biological activity. Oxygen is a vital resource for human exploration; thus, the oxygen survey proposed here for Mars also would yield results that would be useful in human exploration, such as site selection for human exploration. The Viking Gas Exchange Experiment showed that humidifying the Martian regolith at the Viking lander sites released oxygen; so in an indirect way, local concentrations of near-surface oxygen could be indicative of increased humidity. Water is also of interest for exobiological and human explorations of Mars. Finally, data on carbon fixation under Martian conditions, especially Martian concentrations of CO<sub>2</sub>, will be of importance in food and oxygen production on Mars in conjunction with human exploration.

## Progress and results

If life were present on Mars today, it would face potentially lethal environmental conditions such as a lack of water, frigid temperatures, ultraviolet radiation and soil oxidants. In addition, the Viking missions did not detect near-surface organic carbon available for assimilation. Autotrophic organisms that lived under a protective layer of sand or gravel would be able to circumvent the ultraviolet radiation and lack of fixed carbon.

Two photosynthetic near-surface microbial communities have been identified, one in the intertidal and supertidal of Laguna Ojo de Liebre (Baja California Sur, Mexico) and one in the acidic (pH ~2.2) gravel near several small geysers in Yellowstone National Park (Wyoming, U.S.A.). Both communities were studied in the field with respect to their ability to fix carbon (fig. 1), including elevated levels of inorganic carbon (fig. 2). Triplicate samples were incubated in the field in the presence of <sup>14</sup>C-labeled bicarbonate, and acid-stable incorporation of the label analyzed by scintillation spectroscopy. In both cases, carbon fixation was much lower than what would be found with a similar area of grass, but it was certainly significant. While these sand communities have not been exposed to the entire suite of Martian environmental conditions simultaneously, such communities can provide a useful model ecosystem for a potential extant Martian biota.

Previous work had shown that photosynthetic carbon fixation is often enhanced in the presence of additional carbon dioxide (CO<sub>2</sub>). Here we conducted experiments to determine if this CO<sub>2</sub> fertilization effect extended to the subsurface microbial mats. As illustrated in figure 2, the addition of CO<sub>2</sub> had an immediate and dramatic effect on carbon fixation rates.

Oxygen evolution by photosynthetic organisms was also monitored directly. Photosynthetic material (leaves or algae) were placed in a 250 ml Erlenmeyer flask with an oxygen probe (Gas Tech, Inc.) inserted into the flask through a greased one-hole stopper. The oxygen level was monitored, either with or without preincubation, in the dark for up to several days. Controls (no sample or dead sample) showed no detectable change in oxygen concentration. When there was no dark treatment, the oxygen level fluctuated around the mean. With dark preincubation, the oxygen level decreased, and it rose sharply upon exposure to light (fig. 3).

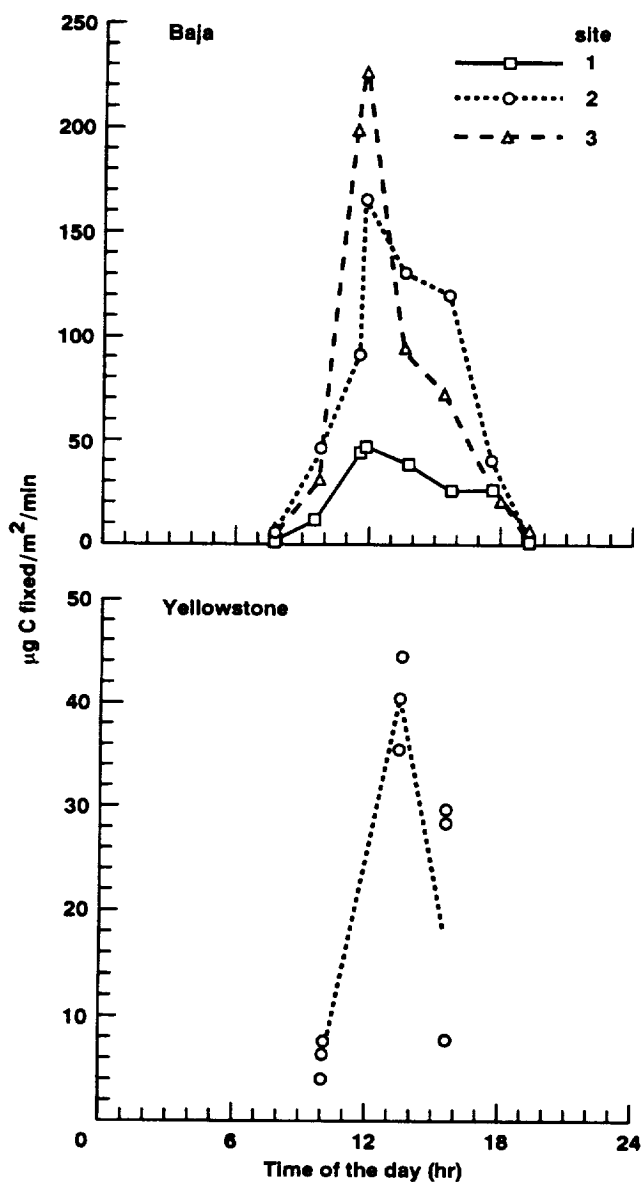


Figure 1. Diurnal patterns of carbon fixation in subsurface mats. Three sites were chosen along the sandy intertidal in Baja, with site 4 closest to the water. The mats were incubated for ~15 min *in situ* in a solution of lagoon water (Baja site) or stream water (Yellowstone) supplemented with  $\text{NaH}^{14}\text{CO}_3$ , and later assayed for acid-stable  $^{14}\text{C}$ . For the Baja samples, each time point represents an average of three incubations; the raw data are shown for the Yellowstone samples.

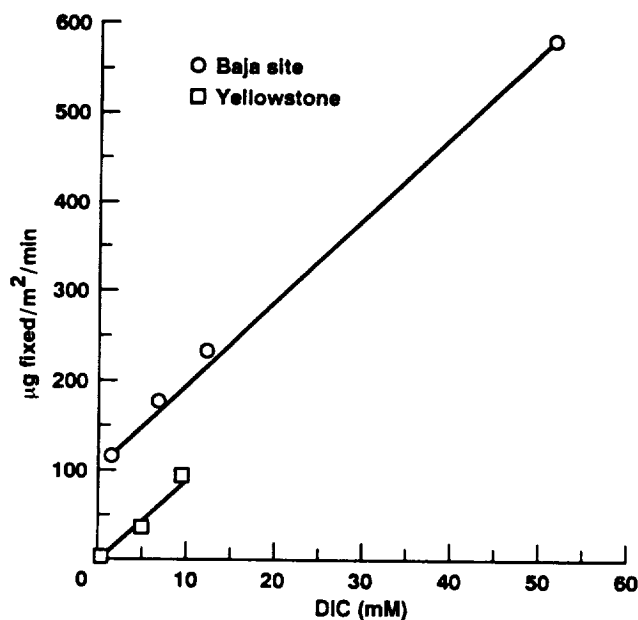


Figure 2. The impact of additional  $\text{CO}_2$  (in the form of dissolved inorganic carbon, DIC) on carbon fixation rates in subsurface mats. The mats were incubated for ~20 min *in situ* in a solution of lagoon water (Baja site) or stream water (Yellowstone) supplemented with  $\text{NaHCO}_3$  and spiked with  $\text{NaH}^{14}\text{CO}_3$ . All experiments were conducted near noon.

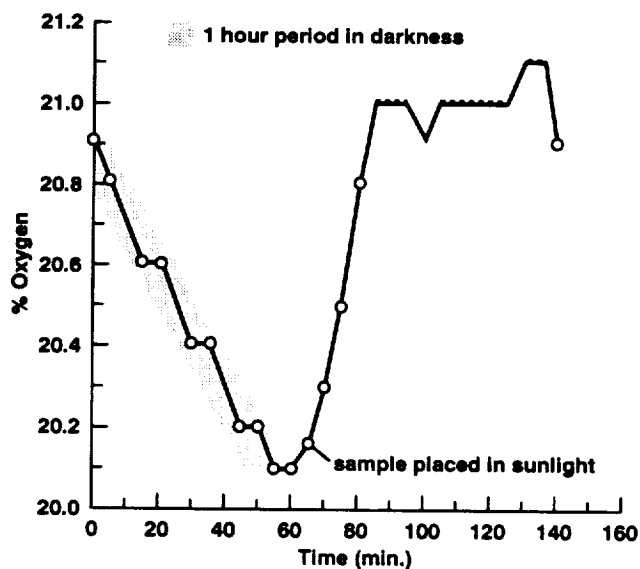


Figure 3. Oxygen evolution by grass. Oxygen levels fell significantly in the dark. Then, oxygen was consumed by respiration but not produced by photosystem II (a process requiring light). When the foil shielding was removed, oxygen production resumed and was easily detected.

### **Significance of the results**

There are several main conclusions from this work. First, carbon fixation (and, thus, oxygen evolution) can occur in protected (Lyngbya) or subsurface (sand) communities in the absence of standing water. This suggests that the levels of oxygen on the surface of these communities may be elevated over ambient levels. Oxygen evolution by photosynthetic organisms can be easily monitored. The signal is greatly enhanced by a short pre-incubation in the dark. Finally, the results would be important for both exobiology and the future human exploration of Mars.

### **Publications resulting from study**

Talk at COSPAR 1992, Washington D.C.,  
September 1992.

Seminar at U.C. Santa Cruz, November 1992.

Article in press (Rothschild, L. J. A "Cryptic" Microbial Mat: A New Model Ecosystem For Extant Life On Mars. Adv. Space Res.).

Article in preparation (Lynn J. Rothschild & Lorraine J. Giver, Carbon fixation in a cryptic microbial mat: A source of organic carbon for beach ecosystems).

### **References**

1. Rothschild, L. J.; and DesMarais, D.: Carbon isotope fractionation and the search for life on Mars. Adv. Space Res., vol. 9, 1989, pp. 159-165.
2. Rothschild, L. J.: Earth analogs for Martian life. Microbes in evaporites, a new model system for life on Mars. Icarus, vol. 88, 1990, pp. 246-260.

# **Infrared Spectra of Microsamples of Cosmic Interest: Diamonds, Silicon Carbide, Interplanetary Dust Particles, and Organic Residues**

## **Investigator**

Scott A. Sandford, Ames Research Center,  
Moffett Field, CA 94035-1000

## **Other personnel involved**

Louis Allamandola, David Blake, and  
Robert Walker, Ames Research Center,  
Moffett Field, CA 94035-1000

## **Objectives of the study**

The purpose of this investigation is to obtain the infrared spectra in the  $4000\text{--}400\text{ cm}^{-1}$  range of a number of different kinds of microsamples of astrophysical interest. These samples include, but are not restricted to, (i) diamond and silicon carbon grains that are found in meteorites that are known from isotopic anomalies to have an interstellar origin, (ii) individual interplanetary dust particles collected in the stratosphere by NASA high altitude aircraft, and (iii) organic residues found in meteorites and produced in laboratory simulation experiments in our low-temperature laboratory.

The spectra from these samples can be used to determine the chemical and mineralogical composition of these samples, thereby allowing us to draw inferences about their formation and subsequent evolution in space. The spectra can also be compared directly to telescopic and remote sensing data. Such comparisons will help identify these materials in space and allow us to better determine their cosmic distribution and abundance.

## **Progress and results**

The lengthy process of procuring the customized infrared microscope needed to carry out this project has been completed and the microscope has been delivered. [Procurement has recognized the PI with a "COTR-of-the-year" award for his part in the sole-source purchase of the instrument.] The microscope, a Nicolet IR Plan, is fully compatible with our Nicolet 740 Fourier transform infrared spectrometer.

The microscope has since been installed with the aid of Nicolet service personnel and Dr. Sandford has completed preliminary tests verifying that the microscope is working up to specifications and is fully compatible with and integrated into the spectrometer

system. These preliminary tests indicate that the microscope is fully capable of carrying out the remainder of the project. As an example of the improvement of our ability to measure the spectra of microsamples, we find that microsamples that once required 2 full days (48 hours) of integration to obtain a high quality spectrum can now be measured in less than 5 minutes! This substantial improvement will allow us to carry out studies that would have been impossible to pursue before delivery of the microscope.

## **Significance of the results**

As the infrared microscope has only just arrived and has been installed, there are (as yet) no substantial scientific results. The tests indicate that there should be no major difficulties in obtaining the spectra of the various types of samples listed above. Indeed, it is expected that it will be more time consuming to obtain and mount the samples for study than it will be to actually measure their spectra.

## **Planned future work**

We intend to spend the majority of the upcoming year's effort on the measurement of infrared spectra from a variety of astrophysically-relevant microsamples. A number of these samples are already available in our laboratory. Other samples will have to be obtained from other investigators or institutions. For example, new samples of interplanetary dust particles will most likely have to be obtained from NASA's Cosmic Dust Collection Program. Particles are collected at Ames and curated at the Johnson Space Center and are available on request, subject to peer review.

Since all of the samples of interest are small ( $< 100\text{ }\mu\text{m}$  in diameter) we will have to acquire and install some facilities for microsample handling and mounting. These include a stereomicroscope, a micromanipulator, and a supply of potassium bromide sample flats. The \$20 K requested for FY 93 in the Fund Report is intended to go towards these requirements.

Once a sample is mounted and data obtained, we intend to use the spectra in a number of ways. In the case of the spectra from meteoritic diamonds and silicon carbide, comparisons will be made with

telescopic data taken from astronomical objects thought to produce these materials. In this way we hope to better determine the chemical and physical environments that create these materials. The spectra of organic materials will be used primarily to identify the various compounds present in the samples with an

emphasis on those compounds that are of interest to exobiology.

**Publications resulting from study:** None so far

**References:** None so far

# Biologically Produced Magnetite and its Relationship to the Banded Iron Formations

## Investigator(s)

D. E. Schwartz, R. L. Mancinelli, and M. R. White, SETI Institute; and V. Oberbeck, Ames Research Center, Moffett Field, CA 94035-1000

## Objectives of the study

Magnetite,  $\text{Fe}_3\text{O}_4$ , is produced both abiotically and biologically. Abiotically, magnetite is a late magmatic mineral and forms as a consequence of the cooling of a magma rich in iron. Biologically, magnetite is produced by several organisms, including magnetotactic bacteria. Biologically-produced magnetite serves several functions including (1) to carry electrons in the cytochrome system, (2) to harden outer surfaces for scraping, and (3) to detect the Earth's magnetic field for navigation. Hematite,  $\text{Fe}_2\text{O}_3$ , is also produced both abiotically and biologically. Abiotically, hematite rarely occurs as a primary mineral in igneous rocks, but it is common as an alteration product, a fumarole deposit, and in some metamorphosed Fe-rich rocks. Biologically, hematite is produced by bacteria and serves as an electron carrier in the cytochrome system. Biologically-produced magnetite, as well as biologically-produced hematite, is formed under the control of the host organism. Consequently, it has distinctive characteristics (including morphologies, structures, and microchemistries) that are unique to the host organism which produced them (Schwartz et al., 1990).

Banded Iron Formations are a sedimentary rock type that commonly occur in Archean and Early Proterozoic terrains. They are typically thinly bedded or laminated, and they contain 15% or more iron (of sedimentary origin) and, commonly, layers of chert (James, 1954). The iron found in these formations is mostly in the form of magnetite. The origin of the Banded Iron Formations remains a great puzzle for several reasons including: their confinement to the Precambrian; iron and silica today show very different chemical behavior than during the Precambrian; and free oxygen had to have been available during this period in Earth's history (which is thought to have been extremely low in  $\text{O}_2$ ). Several theories exist to explain the origin of the Banded Iron Formations (e.g., Cloud, 1972; Goldich, 1973; Dimroth and Kimberly, 1976); but none have been proven. One theory involves the chemical reaction between soluble ferrous iron, with ambient free oxygen resulting in the forma-

tion of ferric and ferro-ferric compounds that became deposited in fine layers at the sediment-water interface. The source of such free oxygen in a proposed anaerobic (oxygen-free) environment is one of the major controversies.

The purpose of this study is to determine if the magnetite and hematite in the Banded Iron Formation was biologically or abiotically produced. To accomplish this, the characteristics of biologically-produced magnetite and hematite (concentrated from *Aquaspirillum magnetotacticum*) and abiotically-produced magnetite and hematite are being compared with characteristics of magnetite and hematite from the Gunflint Banded Iron Formation (Ontario, Canada) using morphological, elemental, and crystallographic analysis techniques.

## Progress and results

Several analytical techniques were employed to determine the characteristics of the magnetite, hematite, and banded iron formation samples. Results of X-ray diffraction analyses of the abiotically-produced magnetite and hematite confirm their composition. Whole rock analysis of the Gunflint Banded Iron Formation revealed the major minerals quartz, hematite, siderite, and dolomite. Minor minerals composing the Gunflint include greenalite, pyrite, pyrrhotite, and apatite. Analysis of a magnetic fraction of the Gunflint showed the minerals quartz, hematite, siderite, dolomite, and a small amount of magnetite. Analysis of the magnetic concentration from *Aquaspirillum magnetotacticum* shows organic compounds along with a relatively large amount of hematite and lesser amounts of magnetite. X-ray fluorescence analysis of the material concentrated from *Aquaspirillum magnetotacticum* shows a strong Fe signature. Excitation with the Fe-K line from an X-ray tube yielded fairly strong K and P peaks.

Results of differential thermal analysis of abiotically-produced magnetite revealed exothermic peaks due to adsorbed water and the oxidation of  $\text{Fe}_3\text{O}_4$  (magnetite) to  $\gamma\text{-Fe}_2\text{O}_3$  (maghemite). Three peak temperatures reflect particle size distribution of the magnetite. The Curie point for magnetite and the transition of  $\gamma\text{-Fe}_2\text{O}_3 \rightarrow \alpha\text{-Fe}_2\text{O}_3$  (hematite) could be inferred from the data. The change in the magnetic properties of  $\alpha\text{-Fe}_2\text{O}_3$  is reflected by a notable exotherm. Results of differential thermal analysis of a sample of partially enriched magnetite ( $\text{Fe}_3\text{O}_4$ ) from



the Gunflint Banded Iron Formation show exothermic peaks due to adsorbed water. Exothermic peaks signaling the oxidation of  $\text{Fe}_3\text{O}_4$  to  $\gamma\text{-Fe}_2\text{O}_3$  are present. Particle size distribution of the magnetite in the sample can be inferred from the peak temperatures. The transition of  $\alpha$ -quartz to  $\beta$ -quartz, the decomposition of siderite, the transition of  $\gamma\text{-Fe}_2\text{O}_3 \rightarrow \alpha\text{-Fe}_2\text{O}_3$ , and the decomposition of dolomite are observed in the spectra. The DTA analysis of magnetite and hematite from *Aquaspirillum magnetotacticum* shows the decomposition of bacterial organic material. Three exotherms signal the oxidation of magnetite to maghemite. The transition of maghemite to hematite can be seen in the spectra. The thermal signature of the magnetite from *Aquaspirillum magnetotacticum* appears to show a greater similarity to that from the Banded Iron Formation than to the abiotically-produced magnetite from Wards Scientific Supply.

### Significance of the results

The mineral identification and particle size distribution data obtained from the differential thermal analyses along with the X-ray diffraction data indicate that the magnetite and hematite from the Gunflint Banded Iron Formation share some similarities with biologically formed magnetite and hematite. This

would suggest that the magnetite and hematite from the Gunflint Banded Iron Formation may be of biological origin. These results, however, are not unequivocal, due to limitations of the techniques. To help discriminate between the two samples, we are conducting analyses using Mössbauer spectroscopy.

**Publications resulting from study:** None so far

### References

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- James, H. L.: Sedimentary facies of iron-formations. *Econ. Geol.*, vol. 49, 1954, pp. 235-293.
- Schwartz, D. E.; and Mancinelli, R. L.: Biomarkers and the search for extinct life on Mars. *Adv. Space Res.*, vol. 9, no. 6, 1989, pp. 155-158.
- Schwartz, D. E.; Mancinelli, R. L.; and Kaneshiro, E.: Using minerals as biomarkers in the search for life on Mars, COSPAR, The Hague, 1990.

# Development of a Direct Measurement Transducer for the Oil Wedge Skin-Friction Technique

## Investigator(s)

H. Lee Seegmiller, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

The objective is to develop a new nonintrusive means of measuring skin friction. The recently developed laser interferometer oil wedge technique is regarded as a reliable and nonintrusive means of obtaining skin-friction measurements in certain flows. In this technique, the thinning rate of a wedge of oil on the model surface is related to the friction force at the oil-gas interface. The oil thickness is determined from alternating constructive and destructive interference between laser beams reflected from the surfaces of the oil and model as the oil wedge thins.

Although reliable results have been obtained with this method, the requirement for optical access prevents its use in the internal flows of nozzles or inlets. The laborious and time-consuming setup of the laser and detector also severely restricts the opportunity to make simultaneous measurements at various model locations, resulting in lengthy and expensive tunnel test programs. Additional limitations of the interferometric method occur when tunnel or model vibrations are present or when model or aircraft structural

deflection occurs in response to aerodynamic or thermal effects.

A new, rugged, flush-mounted transducer is proposed which may make direct measurement of the oil wedge thickness possible. Unlike the laser interferometric method, the proposed transducer would provide a continuous measurement during the thinning of the oil wedge. Furthermore, if a means of exuding the oil through a slit near the transducer can be developed, the method could be used in full scale flight vehicles or large continuously running wind tunnels.

## Progress and results

A new state of the art capacitance bridge has been obtained, and several prototype transducers have been fabricated. Preliminary results indicate sensitivity to oil thickness changes of order 0.1 microns. Further work is required to determine the best configuration and materials for improved thermal stability and a means of accurate calibration.

**Significance of the results:** None so far

**Publications resulting from study:** None so far

**References:** None so far

# Accelerated Overset Grid Generation for Rapid Design Studies with CFD

## Investigator(s)

Reese L. Sorenson, Ames Research Center,  
Moffett Field, CA 94035-1000  
Mohammed Hafez,  
University of California at Davis,  
Davis, CA 95616  
William R. Van Dalsem, Ames Research Center  
Moffett Field, CA 94035-1000

## Other personnel involved

Shishir Pandya,  
University of California at Davis,  
Davis, CA 95616  
Karen McCann, Sterling Software,  
Palo Alto, CA 94303

## Objectives of the study

The greatest impediment to a tremendous expansion in the use of Computational Fluid Dynamics (CFD) in aerospace design is the significant time required to generate grids about complex configurations. Only when the time required to generate the grid for a realistic configuration can be reduced from months to weeks or days, and the effort required to study a proposed design change can be measured in days or hours, will CFD be fully utilized in the aerospace design cycle.

To address these issues, this study has three specific objectives (1) to develop a Graphical User Interface (GUI) for an existing program to generate "collar" surface grids on CFD components by an hyperbolic marching method, (2) develop a "prismatic" volume grid generator, using unstructured surface grids and being structured in the direction normal to the body, and (3) develop a flow solver designed specifically to take advantage of the prismatic grid.

## Progress and results

The GUI for the collar grid program, called SURGRID, has been written and tested. It is now available for general use, and is in use by various researchers. The prismatic grid generator program is in an advanced state of development. It has been used to generate grids (with both inviscid and viscous normal spacing) about isolated fuselage shapes, isolated wings, and

wing/body combinations. A sample of such a volume grid is seen in figure 1. Development of the flow solver has recently begun and completion is expected by Spring.

## Significance of the results

A valuable new computer program is now in the hands of the greater CFD user community. Another will become available shortly, and a third will be available soon.

It is generally thought that grid generation is of two types: structured or unstructured. The prismatic grid approach is neither, but has the advantages of both. Grid generation itself is easy as with unstructured grids. Treatment of geometrically or topologically complex regions is easy, as with unstructured grids. But as with structured grids, it is a simple matter to adjust spacing normal to the body to viscous or inviscid needs. And as with structured grids the connectivity is defined only once, leading to efficient use of computer resources.

The end result of technological improvements such as these is the more widespread use of CFD in the aircraft design cycle. This will mean further reductions in the cost and time necessary to design aircraft.

**Publications resulting from study:** None so far

**References:** None so far

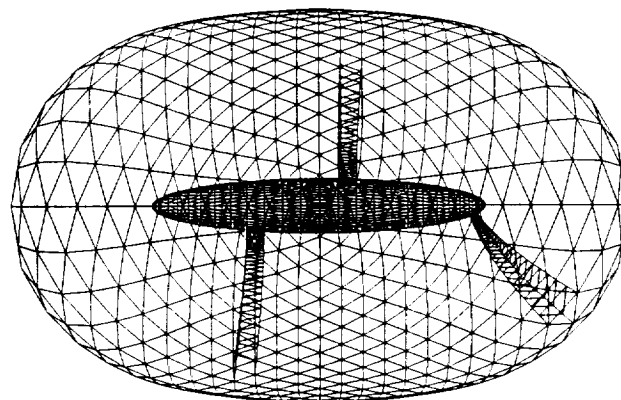


Figure 1. Prismatic grid about ellipsoidal body.

# A Neural Learning Algorithm for Touch-Based Control of Mechanical Manipulation

## Investigator(s)

Jay Steele, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

A fundamental NASA goal is to return an active human presence to the Moon and establish a lunar base. The technological problems facing NASA in this future endeavor to build, maintain, and operate a base in the extremely hostile lunar environment are very challenging. We feel that automating vehicles and manipulators to accomplish tasks in the lunar environment is essential to the successful solution to these NASA problems. Specifically, the ability to safely control the movement of these vehicles and manipulators in a cluttered work space with potentially dynamic obstacles is a critical technology area. The purpose of this study is to develop a new neural learning system capable of handling the control problem of moving these vehicles and manipulators safely around perceived obstacles towards specified goals. The complete system must be capable of learning and storing information about the world, in addition to controlling a physical robot with a real-time control loop.

## Progress and results

To accomplish these objectives, a distributed control system was developed for the robot testbed consisting of a Puma 562 robot arm mounted on a linear track. Using the Task Control Architecture (TCA) system from Carnegie Mellon University, one computer is set up with one process running a central server process (the Central Host module), while another process runs a neural learning/control module. On another computer, a single board computer running VxWorks, a real-time UNIX operating system, runs another process that is the robot control module. This robot

control module controls the robot testbed using a 35 Hz control loop. It collects information from sensors that indicate obstacles in the robot's path, and it stops the robot's motion when necessary to prevent collisions.

The system allows the neural learning/control module to move the robot arm to specific joint positions and to find out if the move was successful. If the specific move failed, due to a sensor-detected collision with an obstacle, the neural learning/control module learns that this is not a good move to make. Ideally, it then selects another move to achieve its long-term goal.

We have developed a reinforcement learning system that learns how to move to specified goal positions by developing an evaluation function for each goal position. It returns the most appropriate action for a given state that will allow the robot to reach its goal safely. This evaluation function is reinforced both by short term success (in this case by getting closer to the specified goal) and long term success (by actually reaching the specified goal). This reinforcement changes the values assigned to all the possible actions at each state, and the action with the highest value (for the current state) is the action commanded to the robot controller.

The next step is to fully integrate this reinforcement learning system to the robot controller and to modify the system for better continuity of knowledge between different evaluation functions for different goal positions.

**Significance of the results:** None so far

**Publications resulting from study:** None so far

**References:** None so far

# Optimizing Spatial Auditory Displays for Multiple Communication Channel Intelligibility

## **Investigator(s)**

Elizabeth M. Wenzel and Durand R. Begault,  
Ames Research Center,  
Moffett Field, CA 94035-1000

## **Other personnel involved**

Phil Stone and Rick Shrum,  
Sterling Software, Ames Research Center,  
Moffett Field, CA 94035-1000

## **Objectives of the study**

The objective of this proposal is to optimize spatial auditory display design technology by gathering and analyzing basic and applied research data on intelligibility as a function of sound source position, bandwidth, and applications context. It is currently unknown what would constitute the optimal parameterization of a spatial auditory display, primarily because signal processing techniques are new, and little or no relevant human factors or psychoacoustic data are available on the subject. The goal is to use existing technology to best advantage within applications contexts such as mission launch control (NTDs), cockpits, and air traffic control stations.

## **Progress and results**

Our DDF was presented in May of 1992, along with the Neilsen award. Paperwork for beginning procurement of experimental equipment and organization of personnel followed availability of funds in June 1992.

Progress made so far has involved preparation for experiments during the second year of the award. As of October 1, 1992, we received 25% of the hardware necessary to begin experiments, but we expected the procurement process to be complete by the end of November. This includes working with our software developer to implement "staircase" experiments; developing models for communication scenarios, in conjunction with the Kennedy Space Center call sign handbook; and designing specialized digital signal processing software for implementing 3-D sound.

**Significance of the results:** None so far

**Publications resulting from study:** None so far

**References:** None so far

# Musculoskeletal Loading or Unloading with Differential Air Pressure

## Investigator(s)

Robert Whalen and Alan Hargens,  
Ames Research Center,  
Moffett Field, CA 94035-1000  
Doug Schwandt,  
Veterans Administration,  
Palo Alto, CA  
Don Watenpugh, Bionetics,  
Mountain View, CA

## Objectives of the study

The objectives of the proposal are (1) to validate the concept of using a difference in air pressure between the upper and lower body in space to load both the cardiovascular and musculoskeletal systems to levels achieved during normal daily activity on Earth, and (2) to simulate "hypogravity" and "hypergravity" locomotion on Earth.

We have proposed to design and fabricate a differential air pressure chamber and treadmill assembly that separates the upper and lower body at the waist using a "frictionless" air-tight seal. Based on theoretical predictions and measurements on test subjects, we estimate that a negative chamber pressure of 100 mmHg (2 psi) will produce a resultant footward force in microgravity approximately equal to one Earth body weight.

We further hypothesize that gait (both walking and running) within the chamber in microgravity will resemble locomotion on Earth in terms of muscle activation patterns, limb segment kinematics, joint moments, ground reaction forces, and internal musculoskeletal forces. If this device proves capable of duplicating 1-g ground reaction force patterns and limb kinematics in microgravity, then the inertial component of vascular pressure will be similar to pressures achieved during normal locomotion on Earth.

A major advantage of this innovative concept is that astronauts will be able to maintain their normal Earth-bound activity levels while in space. Other research studies have also indicated that with higher force levels, exercise time to maintain musculoskeletal tissue

function may be reduced. This device will also allow us to increase proportionally the level of musculoskeletal force by increasing lower body negative pressure.

## Progress and results

The design of the differential pressure system is nearly complete and is taking place in parallel with the manufacturing procedure. A sophisticated computer controlled feedback air pressure control system that utilizes two servo butterfly valves in line with a vacuum and pressure source, respectively, has been built and is awaiting completion of the chamber for testing. The control system accepts a wide range of variables including physiological measures and accelerations as inputs to the pressure control. In addition any pressure time profile can be programmed. A commercial powered treadmill is being modified to fit within the acrylic chamber.

The project is on schedule and a working prototype was scheduled for completion by the end of 1992. Research objectives for 1993 remain unchanged from the initial proposal. We have been in contact with JSC regarding a KC-135 flight in the summer of 1993. A pilot project with the Palo Alto Veterans Administration has been initiated with the aim of using the device for rehabilitation.

**Significance of the results:** None so far

## Publications resulting from study

1. Patent # 5,113,339: "Exercise Method and Apparatus Utilizing Differential Air Pressure," Inventors: Robert Whalen and Alan Hargens, 1992.
2. Whalen, et al.: Musculoskeletal loading or unloading with differential air pressure. 37th Annual Meeting of the ORS 16/2:628, 1991.
3. Hargens, et al.: Lower Body Negative Pressure to Provide Load Bearing in Space. *Aviat. Space Environ. Med.*, vol. 62, 1991, pp. 934-937.

**References:** None so far

# Stabilized Zirconia Aerogel Advanced Material Development

## Investigator(s)

Susan White, Ames Research Center,  
Moffett Field, CA 94035-1000

## Objectives of the study

The goals are to produce a new class of materials: fiber-loaded refractory aerogels, and to explore their potential for TPS use. Aerogels, sometimes called "solid smoke," have the potential for being a breakthrough material because of their extremely light weight. However, we need to contend with their most profound weaknesses: mechanical fragility and very high surface activity. The approach taken is twofold: to solve the strength problem by producing a set of fiber-loaded stabilized Zirconia samples, characterizing their material properties, and optimizing the composition and processing. Solving the surface activity problem will result in a higher use temperature. This involves chemically bonding more atoms to the hydroxyl groups on the aerogel itself.

## Progress and results

The first known samples of fiber-reinforced stabilized Zirconia aerogel were successfully produced. To date, twenty-five samples have been produced. The test matrix included various fiber-loading, chemical processing methods, and heat-treatment conditions. A fiber loading of 12% by weight minimized the end-product density samples. To produce sufficiently strong samples, the required heat treatment temperatures and times have been roughly quantified at 1350°C for 10 hours. SEMs of the materials show the microstructure.

To solve the problem of the very high surface activity characteristic of aerogels, Silica aerogels were used as a testbed because the chemistry is already well understood. The approach involves chemically bonding extra silicon atoms to the hydroxyl groups bound to the aerogel structure itself. This is accomplished by transporting the silicon into the aerogel, bound to gaseous phase and decomposing it thermally once it has entered the structure. These tests are being set up and will start in mid-October, 1992.

Numerical modeling of the radiation properties has produced two initial models and a series of computed radiation transport properties for several cases: to predict the phase function, extinction coefficient, and reflectance of slabs of such materials.

## Significance of the results

The goal of the first phase was to create a new class of lightweight, mechanically strong, high temperature insulation materials. Several samples of fiber-loaded Zirconia aerogels have been produced, and enhanced mechanical strength has been exhibited. If successful, the novel approach of fiber-loading aerogels should apply to different, much more refractory materials. Stabilized Zirconia was chosen for a fast and relatively inexpensive test of this concept because the necessary fibers and chemical precursors are commercially available. In addition, an approach was undertaken to reduce the surface activity of these finely-divided materials, with the goal of increasing the sintering temperature.

**Publications resulting from study:** None so far

**References:** None so far

# Predicting Lyme Disease Risk: A Remote Sensing Model Based on Landscape Epidemiology

## Investigator(s)

Byron L. Wood, James G. Lawless, Louisa R. Beck, Sheri W. Dister, Ames Research Center, Moffett Field, CA 94035-1000  
Durland Fish, New York Medical College, Valhalla, NY 10595

## Objectives of the study

Lyme disease is currently the most prevalent, widely distributed and rapidly increasing vector-borne disease affecting humans in the United States and north temperate regions of the globe. Field studies by investigators at the New York Medical College (NYMC) in Westchester County, New York, have shown that tick populations and disease risk exhibit considerable variability along an urban to rural gradient. This gradient can be described in terms of landscape features such as woodlands and residential developments with high-, medium- and low-density vegetation which are likely locations for contact between humans and infected ticks. The goal of this research is to develop a remote sensing-based spatial model to describe key landscape features and predict areas where humans are at greatest risk of acquiring Lyme disease.

## Progress and results

Landsat Thematic Mapper data acquired in the spring of 1992 were processed to create a map of Westchester County showing 13 land-cover classes, including two deciduous and four residential classes based on vegetation density. This land-cover classification was field checked by NASA and NYMC investigators in August 1992. Data on canine serology (a measure of Lyme disease prevalence) were compared with measurements of the percent of area in each land-cover class and the ratio of deciduous to residential (D/R) for all 25 municipalities in the county. In the northern (rural)

portion of the county, the D/R ratio was 6.29; 62.4% of the canine samples were positive for Lyme disease. In the central and southern (increasingly urban) portions of the county, the average D/R ratio decreased to 2.28 and 0.48, respectively. Positive canine serology in the central and southern areas decreased to 37.6 and 19.0%, respectively.

## Significance of the results

These preliminary results suggest that remote sensing data can be used to identify and map landscape elements associated with risk of Lyme disease. It should therefore be possible to develop a spatial model to predict the patterns of Lyme disease risk. A paper summarizing these preliminary results has been submitted to the 7th Annual Symposium on Geographic Information Systems in Forestry, Environmental, and Natural Resources Management, to be held in February 1993, in Vancouver, British Columbia.

## FY93 research

Research in FY93 will focus on analysis of the spatial patterns (i.e., location, size, shape, area, and perimeter) of key landscape features (i.e., the deciduous and residential classes) associated with Lyme disease risk. The results of these analyses will be used to develop a spatial model to predict areas of greatest human risk. These predictions will be validated in Westchester County by NASA and NYMC investigators. The results will provide the basis for a series of joint NASA/NYMC papers and proposals to the National Institutes of Health (for research in the United States) and the U.S. Agency for International Development (for research in Europe).

**Publications resulting from study:** None so far

**References:** None so far



## APPENDIX

For each of 45 projects sponsored in FY 1992, a brief description and the financial distribution and status follow. Included is the status report on one project that has no narrative report. The reports are arranged alphabetically by the last name of the first investigator.





Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Feasibility Study for an X-ray Diffractometry Instrument with X-ray Fluorescence Capabilities for Remote Planetary Missions

Investigator(s) (show affiliation) David F. Blake, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	<u>FY91</u>	Expected completion date	<u>FY92</u>
Total prior to FY92	<u>\$40,000</u>		Authorized in FY92	<u>\$40,000</u>
Total expended in FY92:	<u>\$40,000</u>	(Estimated)	Requested for FY93, if any	
In-house	<u>\$20,000</u>			
Contracts (identify)	<u>\$20,000</u>	(Friedemann Freund, SETI Institute)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) Grant submitted to PIDP

to Program (name?) Planetary Instr. Def. to Other (identify) \_\_\_\_\_

## Purpose of investigation

To investigate a geometry and instrument capability for combined X-ray diffraction and X-ray fluorescence. Once a design is chosen, a breadboard instrument will be constructed to demonstrate the capability for a potential remote planetary instrument.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Planetary Instrument Definition Proposal, "X-ray Remote Sensing and In-Situ Spectroscopy for Planetary Exploration Missions." Submitted jointly by Goddard Spaceflight Center, Los Alamos National Laboratories, and Ames Research Center.

Discovery Mission Concept Proposal, "CHEMIN: Chemistry and Mineralogy using Combined X-ray Fluorescence and X-ray Diffraction." Submitted jointly by Los Alamos National Laboratories and Ames Research Center.

Blake, D. F., C. Bryson, and F. Freund (1992). "Design of an X-ray Diffraction/X-ray Fluorescence Instrument for Planetary applications." LPSC XXIII, pp. 117-118.

A patent is being applied for covering certain aspects of the detection and X-ray processing schemes. The co-inventors are David Blake, Charles Bryson and Friedemann Freund.

## Planned future work

We intend to continue with the instrument design and construction. We have ordered the necessary components for the CCD camera, but they haven't arrived yet. We hope to receive funding through PIDDP, NRA 92-055A-6.

Prepared by David F. Blake Org. Code SSX MS 239-4 Phone (415) 604-4816



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Radical Measurement by Zeeman Spectroscopy (RAMZES): A Prototype Instrument for Airborne Measurements of Radical Molecular Species

Investigator(s) (show affiliation) Thomas Blake, Charles Chackerian, Jr., and James Podolske, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY92
Total prior to FY92		\$40,000	Authorized in FY92	\$40,000
Total expended in FY92:	\$48,000	(Estimated)	Requested for FY93, if any	
In-house				
Contracts (identify)				
Grants (identify)				

Status of study    ☒ Completed in FY92    ☒ Terminated in FY92    ☐ Continued in FY93

If continued in FY93    ☐ with funds remaining?    ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

                                 to Program (name?) \_\_\_\_\_    to Other (identify) \_\_\_\_\_

**Purpose of investigation**

To develop a laboratory prototype for an ultra-sensitive detector which can be used for the quantitative measurement of free radicals in the Earth's stratosphere.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

**Planned future work**

Will submit a proposal to NASA to incorporate a multiple reflection absorption cell in our solenoid and to acquire a low noise current supply for our laser.

Prepared by C. Chackerian    Org. Code SGP    MS 245-4    Phone (415) 604-6300



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Plasma Spraying of Nonoxide Ceramic Coatings Using a Constricted Arc Jet

Investigator(s) (show affiliation) Jeffrey Bull and Paul Kolodziej, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$25,000		Authorized in FY92	\$40,000
Total expended in FY92:	\$25,000	(Estimated)	Requested for FY93, if any	
In-house	\$6,580			
Contracts (identify)	\$18,420	\$16,220	Aerotherm Corporation; \$2,200	Babitt Bearing Co., Inc.
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

To demonstrate that a cohesive and adherent zirconium diboride ( $ZrB_2$ ) coating can be plasma sprayed using a constricted arc jet.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

**Planned future work**

Initial experimentation has been completed at Aerotherm Corporation with encouraging results. Because of the high cost of operating at Aerotherm and the need to conduct a large number of experiments, steps have been taken to obtain a 5-MW constricted arc jet and have it installed here at Ames. Negotiations to this effect are in progress with Sandia National Laboratory. It is anticipated that FY92 funds will be spent on the installation and refurbishment of this constrictor.

Prepared by Jeffrey Bull Org. Code RTM MS 234-1 Phone (415) 604-5377



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation MIR Study of Disks Around Young Stellar Objects

Investigator(s) (show affiliation) Harold M. Butner and Fred Witteborn, Ames Research Center,  
Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$25,000
Total expended in FY92:	\$25,000	(Estimated)	Requested for FY93, if any	\$28,000
In-house				
Contracts (identify)	\$25,000	(Center for Star Formation)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

Disks may be common around young stellar objects. Understanding the physical conditions has important implications for planet formation models. Mid-infrared or MIR emission from disks arises on scales similar in size to our own solar system. We are combining improved radiative transport models with high resolution mid-infrared observations for a number of young stellar objects. Through these models, we will constrain the disks' physical parameters.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Initial work being published in Butner, H. M., Natta, A., and Evans, N. J. II, *Astrophysical Journal*, submitted (1992), "Spherical Disks: Moving Towards a Unified Source Model for L1551."

Poster Paper presented at Center for Star Formation Workshop, Berkeley, CA 9/92 by H. Butner; "Spectral Energy Distributions of Embedded YSO's: With and Without Disks"

**Planned future work**

Add additional physical components to models (ex, scattering term).

Analyze a sample of T Tauri stars (solar mass young stars) where new high resolution mid-infrared emission has been obtained.

Prepared by Harold Butner Org. Code SSA MS 245-6 Phone (415) 604-4217



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Origin of Life: Exploration of the Water/Air Interface as a Reaction Zone

Investigator(s) (show affiliation) Sherwood Chang, Ames Research Center, Moffett Field, CA 94035-1000  
Anastassia Kanavarioti, University of California, Santa Cruz, CA 95064

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$40,000		Authorized in FY92	\$32,000
Total expended in FY92:	\$32,000	(Estimated)	Requested for FY93, if any	
In-house				
Contracts (identify)	\$27,000	(NCA2-650)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

To determine the influence of water/air interfaces on the early Earth, as occur in bubble formation at the sea surface, in thermal springs and hydrothermal systems and in clouds, on model reactions of prebiotic interest.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

**Planned future work**

Study the effects of aerosols produced by bubble bursting using similar model chemical reactions.

Prepared by S. Chang Org. Code SSX MS 239-4 Phone (415) 604-5733



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Human Exploration Demonstration Project

Investigator(s) (show affiliation) Edward Chevers and David Korsmeyer, Ames Research Center,  
Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY94
Total prior to FY92	\$80,000		Authorized in FY92	\$162,000
Total expended in FY92:	\$162,000	(Estimated)	Requested for FY93, if any	\$310,000
In-house	\$162,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

A multi-division effort to integrate a set of Ames technologies into a planetary habitat testbed.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

"NASA Lunar Surface Habitat and Remote Exploration Project," SAE 921194, Y. A. Clearwater.

"The Development of the Human Exploration Demonstration Project: A Planetary Systems Testbed,"  
E. S. Chevers and D. J. Korsmeyer.

## Planned future work

At the end of 1992, the HEDP has finished phase I of the project and is into phase II. This second phase focuses on the implementation and initial integration of the project's component technologies. Phase III, the physical installation of the final testbed, will begin in October of 1993. Phase IV, the system integration and checkout phase, will begin in January of 1994. The demonstration phase of the project will begin in April of 1994.

Prepared by D. Korsmeyer Org. Code FI MS 269-1 Phone (415) 604-3114





Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Development of Fiber-Optic Acoustic Sensors for Wind Tunnel Applications

Investigator(s) (show affiliation) Y. C. Cho and P. T. Soderman, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$80,000
Total expended in FY92:	\$60,000	(Estimated)	Requested for FY93, if any	\$20,000
In-house	\$60,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To develop fiber-optic interferometric acoustic sensors for wind tunnel applications.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A fiber-optic interferometric sensor was developed, fabricated, and tested in an anechoic chamber.  
SPIE Paper 1795-04, 1992.

## Planned future work

Further tests will be performed in the anechoic chamber and later in the wind tunnel. New sensor heads will be designed and tested. Electronics will be modified to accommodate wider frequency band.

Prepared by Y. C. Cho Org. Code RFR MS 260-1 Phone (415) 604-4139



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Propulsion Instrumentation Research Chamber

Investigator(s) (show affiliation) Timothy R. Conners, L. Dean Webb, Sheryll A. Powers, and Ronald J. Ray,  
Ames Dryden Flight Research Facility, Edwards, CA 93523-0273

Funding	Year Initiated	FY90	Expected completion date	FY93
Total prior to FY92	\$35,000		Authorized in FY92	\$35,000
Total expended in FY92:			Requested for FY93, if any	
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

To develop a low cost facility for testing instrumentation designed for propulsion systems. The propulsion instrumentation research chamber (PIRC) was created to accelerate the transition of new technology nonintrusive sensors to the in-flight propulsion system environment. The PIRC has been designed to fit between a bellmouth and an F100 turbofan engine on a ground test stand. It will accommodate many different types of sensors. Hands-on experience can be gained at a low cost per test.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Aerometrics, a phase II SBIR award recipient via Dryden, has expressed a desire to use the PIRC in FY93 to accelerate their development of a compact laser velocimeter for in-flight inlet flow analysis.

**Planned future work**

In addition to the cooperative work that we plan to do with Aerometrics, we are also in the process of acquiring additional customers. Pratt & Whitney, the Navy flight test center, and the University of Nevada have all expressed interest in piggy-backing experiments on the PIRC. The PIRC will be a long term asset to our work in the Propulsion and Performance branch at Dryden. Remaining funds will be used to support test costs.

Prepared by Timothy R. Conners Org. Code XRP MS D-2002 Phone (805) 258-3324



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation A Prototype Infrared Gas Analyzer for Characterizing Plant Growth during Space Flight

Investigator(s) (show affiliation) James Connolly, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Design a prototype CO<sub>2</sub> analyzer specific to space plant growth studies. Also provide detailed documents for a future flight-like system.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

In FY92, feasibility studies were conducted. Also design models were constructed. No patents or awards were received.

## Planned future work

Begin modifying various subsystems based on the feasibility study results of FY92. Construct data analysis routines. Provide documentation for the design of future flight-qualified analyzers.

Prepared by Raman Sargis Org. Code SAR MS 239-7 Phone (415) 604-1253



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Improving Photometric Extrasolar Planetary Detection

Investigator(s) (show affiliation) Laurance Doyle and Kent Cullers, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$38,000
Total expended in FY92:	\$38,000	(Estimated)	Requested for FY93, if any	\$38,000
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Improve detection probability of extrasolar planets by the photometric (transit) method by using pre-determined axis inclinations of stars.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Catalogue of stellar rotation axis inclinations to be submitted for publication this year.

## Planned future work

Observations of eclipsing binary stars for evidence of extrasolar planetary systems.

Prepared by L. R. Doyle Org. Code SI MS 244-11 Phone (415) 604-1372



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation A Resonant Ge:Ga Far Infrared Photoconductor

Investigator(s) (show affiliation) Jam Farhoomand, Orion TechnoScience, Palo Alto, CA and  
Robert E. McMurray, Jr., Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	<u>FY91</u>	Expected completion date	<u>FY93</u>
Total prior to FY92	<u>\$35,000</u>		Authorized in FY92	<u>\$35,000</u>
Total expended in FY92:	<u>\$32,000</u>	(Estimated)	Requested for FY93, if any	<u></u>
In-house	<u>\$27,000</u>			
Contracts (identify)	<u>\$5,000</u>	(Lawrence Berkeley Labs., Interagency Agreement)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?If transitioned to other funding, to RTOP (number?) to Program (name?)  to Other (identify) 

## Purpose of investigation

Development of a photoconductive detector for far-IR wavelengths that is able to achieve unit quantum efficiency at a specified wavelength.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

## Planned future work

Continuation of testing and optimizing of gold coatings to achieve exact reflectivity required for unit quantum efficiency.

Prepared by Robert E. McMurray, Jr. Org. Code SFO MS 244-10 Phone (415) 604-3179



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Investigation of the Scales of Turbulence in Hypersonic Rarefied Flow

Investigator(s) (show affiliation) William J. Feiereisen, Ames Research Center, Moffett Field, CA 94035-1000  
Donald Baganoff and Sanjiva Lele, Stanford University, Stanford, CA 94305

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

The aim of the work is to determine, for the case of intense turbulence in a rarefied flow, whether the predictions of the Navier-Stokes equations agree with the predictions of a particle simulation; if they differ, how they differ, and what impact this has on the process of modeling turbulence by use of the Navier-Stokes equations.

Three questions are being investigated: (1) Can turbulence exist under conditions corresponding to high speed flight in the upper atmosphere? (2) Do the dissipation length scales become of the same order of magnitude as the mean free path, and what implication would this have for the modeling of these scales? (3) Can a Monte Carlo simulation method be used to produce a direct simulation of turbulent flow under rarefied conditions?

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Goswami, A., Baganoff, D., Lele, S., Stanford University, Feiereisen, W., NASA Ames, "A comparative study of turbulent decay using Navier-Stokes and discrete particle simulations," 45th Annual Meeting, Fluid Dynamics Division, American Physical Society, November 22-24, 1992, Florida State University.

**Planned future work**

The initial study has concentrated on two dimensions in order to reduce computation time while assessing feasibility. The comparisons in two dimensions, very surprisingly, do not exhibit basic differences. Further work in the second year of study will pursue the question in a three-dimensional flow capable of generating turbulent kinetic energy.

Prepared by William J. Feiereisen Org. Code RTAC MS 230-2 Phone (415) 604-4225



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Fully-Coupled Structural Deformations and Computational Fluid Dynamics: Direct Solutions Using Newton's Method

Investigator(s) (show affiliation) Fort Felker, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY92
Total prior to FY92		\$40,000	Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☒ Completed in FY92 ☐ Terminated in FY92 ☐ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

Develop a method to directly solve static aeroelasticity problems. Investigate accuracy, cost, and convergence.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

2 conference papers  
2 journal articles  
1 Ph.D. Thesis

**Planned future work**

Will eventually extend to three dimensions. Near-term application to optimum aerodynamic design.

Prepared by Fort Felker Org. Code FFR MS T-42 Phone (415) 604-6096



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Analytical and Experimental Studies of Rotorcraft Vertical Climb Performance

Investigator(s) (show affiliation) Fort Felker, Ames Research Center, Moffett Field, CA 94035-1000  
Robert McKillip, Continuum Dynamics, Inc., Princeton, NJ

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	
In-house				
Contracts (identify)	\$40,000	(Princeton)		
Grants (identify)				

Status of study    ☐ Completed in FY92    ☐ Terminated in FY92    ☒ Continued in FY93

If continued in FY93    ☐ with funds remaining?    ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

                    to Program (name?) \_\_\_\_\_    to Other (identify) \_\_\_\_\_

## Purpose of investigation

Develop an accurate methodology for rotor performance in vertical climb.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

## Planned future work

Experimental portion completed in FY92.  
Will complete analytical effort in FY93.

Prepared by Fort Felker    Org. Code FFR    MS T-42    Phone (415) 604-6096





Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Continuous-Flow Apparatus for Studies of Gas- and Liquid-Phase Adsorption Dynamics

Investigator(s) (show affiliation) John E. Finn and Sanford S. Davis, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Validate theory and simulation code for gas- and liquid-phase adsorption columns (for life support systems) using an apparatus which enables precise operating conditions control and continuous analysis of column effluent.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Results not yet published but have been reported to Headquarters. Interest in validated code has been expressed by other NASA centers and by aerospace contractors.

## Planned future work

Add mass spectrometer when it arrives, complete multicomponent experiments, design and begin assembly of liquid phase apparatus, complete simulation code validation and user interface.

Prepared by John E. Finn Org. Code SAR MS 239-11 Phone (415) 604-1028



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Development of Modal Filtering Techniques for On-Line Estimation of Structural Vibration Parameters

Investigator(s) (show affiliation) Lawrence C. Freudinger, Ames Dryden Flight Research Facility, Edwards, CA 93523-0273

Funding	Year Initiated	<u>FY92</u>	Expected completion date	<u>FY93</u>
Total prior to FY92	<u>                    </u>		Authorized in FY92	<u>\$40,000</u>
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	<u>\$40,000</u>
In-house	\$25,000			
Contracts (identify)	\$15,000	(University Consortium NCA2-642)		
Grants (identify)				

Status of study    ☐ Completed in FY92        ☐ Terminated in FY92        ☒ Continued in FY93

If continued in FY93    ☐ with funds remaining?        ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?)                     

                    to Program (name?)                             to Other (identify)                     

**Purpose of investigation**

To develop an emerging theory known as Discrete Modal Filtering for the purpose of observing the vibration dynamics of nonstationary mechanical systems.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

- Final report, University Consortium NCA2-642.
- Conference paper.
- Software program and data acquisition system software.

**Planned future work**

- Implementation of estimation schemes and performance studies.
- Additional software enhancements.
- At least two additional reports.
- Application of developments to aircraft ground testing.

Prepared by Lawrence C. Freudinger Org. Code XRDV MS 4840D Phone (805) 258-3542



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Computational Modeling of Femtosecond All-Optical Switches Directly from Maxwell's Equations

Investigator(s) (show affiliation) Peter M. Goorjian, Ames Research Center, Moffett Field, CA 94035-1000  
Allen Taflove, Northwestern University, Evanston, IL 60208

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$28,000			
Contracts (identify)				
Grants (identify)	\$12,000	(NCA2-727)		

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Develop algorithms and computer codes for modeling femtosecond all-optical switches and logic gates on a 10-nanometer scale with the full-vector, nonlinear Maxwell equations.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

1. IEEE Journal of Quantum Electronics, Oct. 1992.
2. IEEE AP-S International Symposium, Chicago, IL, July 18-25, 1992, Invited Paper.
3. IEEE AP-S International Symposium, Chicago, IL, July 18-25, 1992, 2nd Invited Paper.
4. Amer. Physical Soc., Div. Atomic, Mol. & Opt. Physics Annual Meeting, Chicago, IL, May 20, 1992, Paper.
5. Optical Soc. Amer., Photonics Topical Meeting, New Orleans, LA, April 13-15, 1992, Paper.
6. Optics Letters, Vol. 17, No. 3, Feb. 1, 1992.
7. AIAA 30th Aerospace Sciences Meeting, Reno, NV, Jan. 6-9, 1992, Paper 92-0457.

## Planned future work

Continue algorithm and computer code development and applications to all-optical switches. Specifically (1) model X-junction switches in two dimensions and (2) extend computer code from two-dimensional simulations to three-dimensional simulations.

Prepared by Peter M. Goorjian Org. Code RFC MS 202A-2 Phone (415) 604-5547



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Gravity Modulation of Tension/Compression Effects on Cellular Responses

Investigator(s) (show affiliation) R. A. Grymes, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

We are investigating two fundamental environmental stimuli—the attachment to extracellular matrix and the tensional dynamic—in relation to the effects of microgravity exposure in cultures of human skin cells. The skin wound model provides excellent insights into the growth, migration, and differentiation behaviors of cells. We have acquired a Flexcell® unit which, using flexible-bottom culture plates (coated with collagen or other matrix macromolecules), transfers cyclic tension to adherent cultured cells. Regulated, reproducible stresses are induced in culture plates positioned on a gasket support connected to a vacuum pump, producing directional force. Cellular function depending critically on growth factor signals, on matrix interactions, and on experienced tensional stresses, can be studied.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

**Planned future work**

In FY92, we designed a clinostat system to deliver constant vectorial gravity modulation to cells attached to a solid support. We completed a market survey, acquired a prototype unit, and completed preliminary experiments. In FY93, we will complete necessary modifications to a new unit. Using our growth curve and cytokine dosage results, we will continue to refine and pursue our experiments. The addition of M. V. Brown, a NASA-JOVE Fellow, will enable us to study cellular ultrastructure and the cytoskeleton using both specific antibody reagents visualized by fluorescence microscopy and electron microscopic techniques.

Prepared by R. A. Grymes Org. Code SL MS 239-11 Phone (415) 604-3239



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Domain Decomposition Approach to Solve Multidisciplinary Fluid/Structure Interaction Problems

Investigator(s) (show affiliation) Guru P. Guruswamy, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$40,000		Authorized in FY92	\$40,000
Total expended in FY92:	\$33,000	(Estimated)	Requested for FY93, if any	
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) HPCC to Other (identify) \_\_\_\_\_

## Purpose of investigation

Develop efficient interfacing techniques between finite difference (FD) based fluid grids and finite-element (FE) based structural nodes. These new interface techniques are tested on simple model problems. Procedures to use this development to solve larger three-dimensional problems associated with complex geometries such as full aircraft are addressed.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Under this project two interfacing techniques are developed based on (1) consistent load approach, and (2) virtual surface approach. In the consistent load approach, the data between the FD grids and the FE nodes are transferred using equivalent work approach. In the virtual surface approach, a grid layout is selected independent of FD and FE grids. The FD data and FE data are both mapped onto this common surface. The order of accuracy can be increased by selecting suitable shape functions for the common surface based on the FE approach.

## Planned future work

The present development will be used in computational aeroelasticity research projects associated with High Speed Civil Transport and High Performance Computing and Communication.

Prepared by Guru P. Guruswamy Org. Code RFA MS 258-1 Phone (415) 604-6329



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Deuterium Abundance in the Interstellar Medium

Investigator(s) (show affiliation) Michael R. Haas and Alexander G. G. M. Tielens, Ames Research Center,  
Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$1,000			
Contracts (identify)	\$39,000			
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To determine the deuterium abundance in the interstellar medium by observing several rotational lines of HD and H<sub>2</sub> in shocked interstellar gas.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

This study just began in July 1992, so there are no results yet.

## Planned future work

We plan to continue the development of the Si:Sb back-illuminated, blocked impurity band detectors and to propose for Kuiper Airborne Observatory flights in FY93.

Prepared by Michael R. Haas Org. Code SSA MS 245-6 Phone (415) 604-5511



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Remote Sensing of Earth's Atmosphere and Surface Using a Digital Array Scanned Interferometer

Investigator(s) (show affiliation) Philip D. Hammer, Francisco P. J. Valero, and David L. Peterson, Ames Research Center, Moffett Field, CA 94035-1000;  
William Hayden Smith, Washington University, St. Louis, MO

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92		\$45,000	Authorized in FY92	\$25,000
Total expended in FY92:		\$25,000 (Estimated)	Requested for FY93, if any	\$35,000
In-house		\$25,000		
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

The objective of our study is to evaluate the capabilities of the DASI (digital array scanned interferometer) class of instruments as future generation imaging spectrometers for terrestrial remote sensing in the visible to mid-infrared. The ultimate objective stemming from this study is to produce and deploy a versatile field instrument which may be applied towards a variety of atmospheric and surface problems.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Poster on DASI instrument progress at 23rd Annual Meeting of Div. for Planetary Sciences of the AAS, Nov. 1991.  
Poster given on preliminary results at the AGU Fall Meeting, Dec. 1991.  
Presentation and abstract of DASI results given at the 11th Int'l Conference on Clouds and Precipitation, Aug. 1992.  
Article on DASI applications is in press: J. Imaging Science (vol. 36), 1992.  
Article on DASI field measurements in preparation: Atmospheric Research, Dec. 1992, to be submitted.

## Planned future work

The optimization of DASI design and performance is planned, using optical ray tracing software for polarized light in birefringent media which we have developed as part of this DDF program.

The construction of an improved version of our original birefringent DASI instrument is planned, using current resources and results from the optical ray tracing software.

The applications of DASIs for remote sensing of the terrestrial environment will continue to be explored, and opportunities for participation in field missions will be sought.

Analysis and publication of results of ongoing work, including the ray tracing algorithm.

Prepared by Philip D. Hammer Org. Code SGP MS 245-4 Phone (415) 604-3383



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Intelligent Dynamic Scheduling Algorithms for Automatic Telescopes

Investigator(s) (show affiliation) B. Hine, M. Drummond, J. Bresina, K. Swanson, A. Philips, R. Levinson, and W. Borucki,  
Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$35,000		Authorized in FY92	\$35,000
Total expended in FY92:	\$35,000	(Estimated)	Requested for FY93, if any	
In-house	\$35,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

This project is an attempt to transfer current state-of-the-art technology in the areas of intelligent scheduling and health monitoring to the operation of automated telescopes. It is a collaborative effort between individuals and groups working in telescope design and control, intelligent scheduling, health monitoring and fault diagnosis, and astronomy.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

1. "Development of a Simplified Operations and Management Structure," Hine and Genet. 1990 Workshop on Small Robotic Telescopes on the Moon.
2. "The APT Planning and Scheduling Manifesto," Drummond, Bresina, Swanson, Philips, and Levinson, 1991 NASA ARC Technical Report #FIA-91-24.
3. "Multi-Use Lunar Telescopes," Genet, et al. in Robotic Telescopes in the 1990's.  
Plus 3 other papers in 1992.

## Planned future work

1993 - Apply scheduling algorithms to field use and measure their performance. Acquire fault diagnosis and health monitoring data from a local telescope.

1994+ - Implement an Antarctic-based robotic telescope as a Lunar mission precursor.

Prepared by B. Hine Org. Code FIC MS 269-3 Phone (415) 604-4379





Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Controlling Lifetimes and Reaction Dynamics of High Energy Density Materials by  
Modifying Chemical Environments

Investigator(s) (show affiliation) Winifred M. Huo, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY92
Total prior to FY92		\$40,000	Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☒ Completed in FY92 ☐ Terminated in FY92 ☐ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To study the effect of chemical environment on the stability of high energy density materials and the possibility of enhancing their stability in storage.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A paper entitled "The Structure and Stability of  $\text{FN}_3$ " by W. M. Huo, T. J. Lee, and P. R. Taylor in preparation for publication in the Journal of Chemical Physics.

## Planned future work

Prepared by Winifred M. Huo Org. Code RTC MS 230-3 Phone (415) 604-6161



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Real Time Automated Diagnosis System for an Animal Holding Facility

Investigator(s) (show affiliation) David L. Iverson and Stephanie Herrin, Ames Research Center,  
Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Investigating techniques for using standard reliability models for automated monitoring and diagnosis.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Applying results to development of a monitoring and diagnosis system for the Research Animal Holding Facility.  
No publications or awards in FY92.

## Planned future work

Deploy the monitoring and diagnosis system during the flight of the RAHF on SLS-2.

Apply results to develop diagnostics for other systems which have undergone reliability analyses (e.g., general purpose workstation (SLS), and portions of Space Station Freedom).

Prepared by David Iverson Org. Code FIS MS 269-4 Phone (415) 604-3115



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Stratospheric Aerosol Particulates: Simulation of Their Morphology, Physical Properties, and Chemistry

Investigator(s) (show affiliation) Richard L. Jaffe, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Carry out molecular simulations of nitric acid-water aerosol particles to determine bulk and surface structure, and to model the sticking of HCl to the surface of a nitric acid-water aerosol.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Project started in February 1992. No papers or reports have been prepared to date.

## Planned future work

Continuing with simulations of aerosol particles as outlined in the original proposal.

Prepared by Richard L. Jaffe Org. Code RTC MS 230-3 Phone (415) 604-6458



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Use of Molecular Fossils to Interpret Paleoenvironments

Investigator(s) (show affiliation) Linda L. Jahnke, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$35,300
Total expended in FY92:	\$35,300	(Estimated)	Requested for FY93, if any	\$37,300
In-house	\$1,400			
Contracts (identify)				
Grants (identify)	\$33,900	(NCC2-695)		

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of Investigation

To understand the synthesis of hopane biomarkers in photosynthetic bacteria and any relationship the presence of these biomarker molecules might have to the evolution of oxygenic photosynthesis.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

## Planned future work

Isolate and characterize the hopanoids of two facultative cyanobacteria. Grow these cyanobacteria under oxygenic and anoxygenic photosynthetic conditions in order to determine what influence such growth might have on synthesis of any potential hopane biomarkers.

Prepared by Linda Jahnke Org. Code SSX MS 239-4 Phone (415) 604-3221



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Pyrosensors for Detecting Chemical Compounds in Planetary Environments

Investigator(s) (show affiliation) Daniel Kojiro and Thomas C. Shen, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92		\$40,000	Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$6,000			
Contracts (identify)	\$34,000	(SETI Institute)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Develop pyrosensors for analyzing oxidants (for example,  $H_2O_2$ , superoxide,  $OH_2$  radical) in Martian soil.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Developed pyrosensors for analyzing  $H_2O_2$  from 10~150ppm.

## Planned future work

Continue to develop more sensitive sensors using different materials.

Prepared by Thomas C. Shen Org. Code SSS MS 239-12 Phone (415) 604-5769



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Study of Ozone Depletion Chemistry Using *Ab Initio* Quantum Mechanical Methods

Investigator(s) (show affiliation) Timothy J. Lee, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To study atmospheric chemistry using *ab initio* quantum mechanical methods, with special emphasis on the study of chlorine, fluorine oxides, nitrogen oxides, and chlorine-nitrogen oxides.

To characterize these compounds with respect to vibrational spectra and thermodynamic stability and also to demonstrate the applicability of *ab initio* methods to the study of atmospheric chemistry.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

An invited talk was presented at the 203rd American Chemical Society National Meeting in San Francisco, April 1992.

Two publications have resulted thus far: T. J. Lee and J. E. Rice, J. Chemical Physics, vol. 97, p. 4223 (1992); T. J. Lee, C. M. Rohlfig, and J. E. Rice, J. Chemical Physics, vol. 97 (1992).

## Planned future work

To continue studies on the structures, vibrational spectra and thermochemistry of the different isomers of  $\text{Cl}_2\text{O}_3$ ; to continue studies of the protonation reaction of  $\text{ClONO}_2$  and determine its importance in the depletion of  $\text{ClONO}_2$  in the Antarctic ozone hole.

Prepared by Timothy J. Lee Org. Code RTC MS 230-3 Phone (415) 604-5208



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Search for Interstellar Molecules in Carbonaceous Meteorites

Investigator(s) (show affiliation) Narcinda R. Lerner and Sherwood Chang, Ames Research Center,  
Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92		\$40,000	Authorized in FY92	\$40,000
Total expended in FY92:	\$36,670	(Estimated)	Requested for FY93, if any	
In-house	\$36,670			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To obtain data that will reveal the D/H distribution in organic compounds found on meteorites as a function of molecular structure and to relate the D/H ratios to possible synthetic pathways originating with deuterium enriched molecules in the interstellar medium.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Paper: The Strecker synthesis as a source of amino acids in carbonaceous chondrites; deuterium retention during synthesis (in preparation).

## Planned future work

Measurement of D/H ratios of compounds extracted from meteorites.

Prepared by Narcinda R. Lerner Org. Code SSX MS 239-4 Phone (415) 604-6941



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Investigations of Supersonic Combustion Using Unique NASA Ames Facilities

Investigator(s) (show affiliation) Gene Menees, Ames Research Center, Moffett Field, CA 94035-1000  
Jean-Luc Cambier and Henry Adelman, Elorete Institute, Palo Alto, CA

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house				
Contracts (identify)				
Grants (identify)	\$40,000	(NCC2-487)		

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To investigate ways to utilize the direct-connect arc-jet facility (DCAF) for Ames hypersonic propulsion experiments. This involves the design of unique combustion experiments and diagnostic procedures along with the use of Ames CFD tools for flow prediction and analysis.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A new state-of-the-art CFD code has been developed which includes vibrational nonequilibrium. This code can be used to simulate combustion experiments in nonequilibrium arc-jet flows. Preliminary studies of unique mixing/combustion experiments have also been initiated (spiralling bifurcated strut, pulsed injection/combustion).

## Planned future work

Apply code to contractor's combustor-nozzle hardware experimental set-up to determine extent of vibrational nonequilibrium. Also, use code to model the proposed mixing/combustion experiments and study appropriate modifications to DCAF for future tests.

Prepared by Gene Menees Org. Code RTA MS 230-2 Phone (415) 604-3465





Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Mixing, Combustion, and Thrust Enhancement by a Pulsed Detonation Wave Augmentor

Investigator(s) (show affiliation) Gene Menees, Ames Research Center, Moffett Field, CA 94035-1000  
Jean-Luc Cambier and Henry G. Adelman, Eloret Institute, Palo Alto, CA

Funding	Year Initiated	FY92	Expected completion date	FY94
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house				
Contracts (identify)				
Grants (identify)	\$40,000	(NCC2-487)		

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Focus on applications of an innovative concept called the Pulsed Detonation Wave Augmentor (PDWA) which uses detonation waves to solve problems facing a supersonic combustion engine (i.e., mixing, combustion efficiency, thrust enhancement, lightweight packaging).

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Preliminary numerical simulations of the interactions between blast waves and mixing layers show a strong influence of detonation over-pressure on mixing efficiency and stagnation pressure losses.

## Planned future work

Determine optimal detonation/combustor pressure ratios by parametric studies for transverse mode of operation. Study axial operating mode of PDWA. Other design options (notably external combustion) will also be examined.

Prepared by Gene Menees Org. Code RTA MS 230-2 Phone (415) 604-3465



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Ablating Surface Heat Transfer Estimation for Flight Application

Investigator(s) (show affiliation) Greg Noffz and Mike Bowman, Ames Dryden Flight Research Facility,  
Edwards, CA 93523-0273

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$20,000			
Contracts (identify)	\$20,000	(PRC)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

To develop a capacitive gage concept capable of measuring the recession of thin-layered ablators, thus quantifying the energy component leaving the surface with the ablation products.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

**Planned future work**

1. Progress to 3rd and 4th generation gage designs.
2. Transition gage evaluation procedure to include actual ablators and/or subliming chemicals.
3. Pursue the analytical analysis of the gage concept.

Prepared by Greg Noffz Org. Code XRA MS D-2045 Phone (805) 258-2417



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation A Miniature, Lightweight Ozone Analyzer for Use on Unmanned Stratospheric Research Aircraft

Investigator(s) (show affiliation) Richard Pearson, Jr., Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	
Total prior to FY92			Authorized in FY92	\$48,000
Total expended in FY92:	\$41,000	(Estimated)	Requested for FY93, if any	\$48,000
In-house	\$41,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☒ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

The purpose of this work is to develop and demonstrate the technology required to build a lightweight, extremely small, low power, continuous measuring *in situ* analyzer for ozone (O<sub>3</sub>) that will operate at altitudes up to 30 km (about 100,000 ft) on high altitude research aircraft.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

1. Developed detailed design for novel optical absorption cell for use in photometer.
2. Wrote a patent disclosure for optical absorption cell design.
3. Wrote a proposal to NASA Headquarters for funding to build flight instrument.
4. Started design for optics to use in a test facility to be built in FY93.

## Planned future work

1. Build a working cell to complete proof of the concept for the optical absorption cell and to obtain data on tolerances needed in fabrication and assembly of optical components.
2. Build a test and evaluation facility to test materials under simulated stratospheric conditions for suitability for use in a photometer. Carry out testing of several potential materials for use in the plumbing and absorption cell.
3. Use a commercially available test and evaluation circuit board to demonstrate feasibility of a novel approach to signal measurement in the photometer. Measure the expected signal to noise ratio in the critical signal acquisition electronics for light intensity measurements.

Prepared by Richard Pearson, Jr. Org. Code SGG MS 245-5 Phone (415) 604-4388



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation Two-Dimensional Polarimetric Observations of the Galactic Center at 10 Microns

Investigator(s) (show affiliation) Yvonne Pendleton, Lynne Deutsch, and Tom Roellig, Ames Research Center,  
Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$16,000
Total expended in FY92:	\$16,000	(Estimated)	Requested for FY93, if any	\$32,000
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**To study the center of the Milky Way galaxy through polarimetric mapping at 10  $\mu$ m.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The polarimeter hardware was completed in March 1992. The software to operate it and the engineering tests are ongoing. Roellig presented a poster paper at the June AAS meeting (Columbus, Ohio) and the abstract was published.

**Planned future work**

1. To continue the necessary lab and telescope tests required to calibrate the instrument.
2. To obtain the observations of the galactic center in June 1993.
3. To analyze the results from item 2.

Prepared by Yvonne Pendleton Org. Code SSA MS 245-6 Phone (415) 604-4391



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Detecting Autotrophic Life on Mars by Surveying for Oxygen

Investigator(s) (show affiliation) Lynn Rothschild, TGS Technology, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY92
Total prior to FY92		\$35,000	Authorized in FY92	\$35,000
Total expended in FY92:	\$35,000	(Estimated)	Requested for FY93, if any	
In-house	\$35,000			
Contracts (identify)				
Grants (identify)				

Status of study ☒ Completed in FY92 ☐ Terminated in FY92 ☐ Continued in FY93If continued in FY93 ☐ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To assess feasibility of detecting life on Mars by surveying the surface of Mars for oxygen.

## FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Talk at COSPAR 1992, Washington, D.C., September 1992.

Seminar at U. C. Santa Cruz, November 1992.

Article in press (Rothschild, L. J.: A "Cryptic" Microbial Mat: A New Model Ecosystem for Extant Life on Mars, Adv. Space Res.).

Article in preparation (Lynn J. Rothschild and Lorraine J. Giver, Carbon fixation in a cryptic microbial mat: A source of organic carbon for beach ecosystems).

## Planned future work

Prepared by Lynn Rothschild Org. Code SGE MS 239-12 Phone (415) 604-6525



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Infrared Spectra of Microsamples of Cosmic Interest: Diamonds, Silicon Carbide, Interplanetary Dust Particles, and Organic Residues

Investigator(s) (show affiliation) Scott A. Sanford, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$30,000
Total expended in FY92:	\$30,000	(Estimated)	Requested for FY93, if any	\$20,000
In-house				
Contracts (identify)	\$30,000	(Purchase of IR microscope)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

The purpose of this investigation is to obtain mid-IR spectra ( $4000-400\text{cm}^{-1}$ ) of microsamples of astrophysical interest. These spectra will be compared to telescopic spectra and will also be used to determine the chemical-mineralogical nature of the samples.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

No papers, reports, or patents. Microscope has been purchased and installed. System integration almost complete. [Procurement awarded S. Sanford a "COTR-of-the-year" award, in part for his part in the sole-source purchase of the IR microscope.]

## Planned future work

As the microscope is now installed and working, we will be concentrating on obtaining and measuring the IR spectra of meteoritic diamonds, silicon carbide, and organics, and (if available) interplanetary dust particles. It is anticipated that this work will lead to 3-5 papers in FY93-95.

Prepared by Scott Sanford Org. Code SSA MS 245-6 Phone (415) 604-6849



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Biologically Produced Magnetite and its Relationship to the Banded Iron Formations

Investigator(s) (show affiliation) D. E. Schwartz, R. L. Mancinelli, M. R. White, and V. Oberbeck, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92		\$33,000	Authorized in FY92	\$30,800
Total expended in FY92:		\$30,800 (Estimated)	Requested for FY93, if any	
In-house		\$6,800		
Contracts (identify)				
Grants (identify)		\$24,000 (NCC2-479)		

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

The purpose of this investigation is to identify characteristics of biologically-produced magnetite and determine if these characteristics are unique to biologically-produced magnetite or if they are also typical of magnetite produced abiotically. Additionally, through this study, we will obtain information on the characteristics of magnetite found in the Gunflint Banded Iron Formation and determine the relationship between biologically-produced magnetite and the magnetite found in the Gunflint Formation.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A paper summarizing our results is currently in preparation.

## Planned future work

Continue characterization of magnetite and hematite extracted from *Aquaspirillum magnetotacticum* and concentrated from the Gunflint Formation. Employ the techniques of differential thermal analysis and Mossbauer spectroscopy to the mineral samples. Compare and contrast results. Continue literature study of magnetite and hematite found in other Banded Iron Formations. Determine relationship between biologically-produced magnetite and hematite and magnetite found in the Banded Iron Formations.

Prepared by D. E. Schwartz Org. Code SSS MS 239-12 Phone (415) 604-3668



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Development of a Direct Measurement Transducer for the Oil Wedge Skin-Friction Technique

Investigator(s) (show affiliation) H. Lee Seegmiller, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$25,000		Authorized in FY92	\$25,000
Total expended in FY92:	\$2,000	(Estimated)	Requested for FY93, if any	\$25,000
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To develop a nonintrusive means of measuring thin liquid layers.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

## Planned future work

Determine best transducer configuration and materials; develop means of calibration.

Prepared by H. Lee Seegmiller Org. Code RFE MS 229-1 Phone (415) 604-6211





Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Accelerated Overset Grid Generation for Rapid Design Studies with CFD

Investigator(s) (show affiliation) Reese L. Sorenson, Ames Research Center, Moffett Field, CA 94035-1000  
Mohammed Hafez, University of California at Davis, Davis, CA 95616  
William R. Van Dalsem, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$40,000		Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	
In-house				
Contracts (identify)	\$5,000	(ICE Contract for computer hardware)		
Grants (identify)	\$35,000	(University Consortium NCA2-655)		

Status of study ☒ Completed in FY92 ☐ Terminated in FY92 ☐ Continued in FY93If continued in FY93 ☐ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

(1) to develop a Graphical User Interface (GUI) for an existing program to generate "Collar" surface grids on CFD components by an hyperbolic marching method, (2) develop a "prismatic" volume grid generator, using unstructured surface grids and being structured in the direction normal to the body, and (3) develop a flow solver designed specifically to take advantage of the prismatic grid.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Although dispersal of funds is complete, the technical work will not be finished until June 1993. To date there have not been any reports, replications, papers, awards, etc.

## Planned future work

Develop and test a new 3D flow solver designed to take advantage of the prismatic grids generated with the computer software written to date pursuant to this study.

Prepared by Reese L. Sorenson Org. Code RFG MS T045-1 Phone (415) 604-4471



Ames Research Center

**Director's Discretionary Fund Report****Fiscal Year 1992**

Title of Investigation A Neural Learning Algorithm for Touch-Based Control of Mechanical Manipulation

Investigator(s) (show affiliation) Jay Steele, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$40,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

**Purpose of investigation**

To design and build a neural learning software system capable of learning how to safely control the motion of robot arms or vehicles around perceived obstacles towards a specified goal within a fixed world reference frame. Then, integrate software with robotic hardware and test out the complete system.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

**Planned future work**

To integrate the neural learning system to the robot controller and to modify the architecture to allow for better continuity of knowledge between different evaluation functions for different goal positions.

Prepared by Jay Steele Org. Code FIC MS 269-3 Phone (415) 604-0158



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Effects of Altered Gravity on Human Smooth-Pursuit Eye Movements

Investigator(s) (show affiliation) Leland S. Stone and Malcolm Cohen, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY91	Expected completion date	FY93
Total prior to FY92	\$40,000		Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	
In-house				
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☒ with funds remaining? ☐ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To measure smooth-pursuit eye movements during centrifugation in order to examine directly the effect of gravity on the sensory processing (both visual and vestibular) underlying the control of a voluntary coordinated movement with minimal Coriolis or biomechanical artifacts.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Eye tracker and supporting data acquisition equipment arrived in May 1992. Calibration, testing and software development is under way. Procurement of equipment, recruiting a programmer, and wind tunnel painting caused major delays.

## Planned future work

Measure smooth-pursuit eye movements in both 1-g and hyper-g environment using the 20g centrifuge.  
Testing of eye tracker on the centrifuge scheduled for Spring 1993.  
Pursuit study in hyper-g scheduled for Summer 1993.

No narrative report

Prepared by Leland S. Stone Org. Code SL MS 262-2 Phone (415) 604-3240

**Fiscal Year 1992**

Investigator(s) (show affiliation) Elizabeth M. Wenzel and Durand R. Begault, Ames Research Center,  
Moffett Field, CA 94035-1000

Status of study      ☐ Completed in FY92      ☐ Terminated in FY92      ☒ Continued in FY93

If continued in FY93      ☐ with funds remaining?      ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

Facilitate communication with multiple channels in contexts such as Kennedy Space Center launch rooms via psychoacoustic investigations of intelligibility under parametric variation of the auditory display.

N/A — (started in June 1992).

Finalize procurement and software development.  
Collect data from experiments; analyze results and prepare report.

Prepared by D. Begault Org. Code FLM MS 262-2 Phone (415) 604-3920



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Musculoskeletal Loading or Unloading with Differential Air Pressure

Investigator(s) (show affiliation) Robert Whalen and Alan Hargens, Ames Research Center, Moffett Field, CA 94035-1000  
Doug Schwandt, Palo Alto Veterans Administration  
Don Watenpaugh, Bionetics

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$18,000			
Contracts (identify)	\$22,000	(NAS2-13273)		
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

The objective of this study is to validate the concept of using a difference in air pressure between the upper and lower body to impose a "non-contact" net external force at approximately the center of mass of the body. We have hypothesized that near normal lower body musculoskeletal forces and fluid pressure distributions will be achieved during walking and running in this device in space.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

U.S. Patent 5,133,339 has been awarded to Robert Whalen and Alan Hargens.

## Planned future work

The project is on schedule and a working prototype was scheduled for completion by end of December 1992. Research objectives for 1993 remain unchanged from the initial proposal. We have been in contact with JSC regarding a KC-135 flight in the summer of 1993. A pilot project with the Palo Alto Veterans Administration has been initiated with the aim of using the device for rehabilitation.

Prepared by Robert Whalen Org. Code SL MS 239-11 Phone (415) 604-3280



Ames Research Center

## Director's Discretionary Fund Report

Fiscal Year 1992

Title of Investigation Stabilized Zirconia Aerogel Advanced Material Development

Investigator(s) (show affiliation) Susan White, Ames Research Center, Moffett Field, CA 94035-1000

Funding	Year Initiated	FY92	Expected completion date	FY93
Total prior to FY92			Authorized in FY92	\$40,000
Total expended in FY92:	\$40,000	(Estimated)	Requested for FY93, if any	\$40,000
In-house	\$5,000			
Contracts (identify)	\$25,000	(TRW)		
Grants (identify)	\$10,000	(LLNL)		

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93

If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

To produce and characterize a set of samples of a new concept in lightweight, mechanically strong, high-temperature insulation materials: fiber-loaded aerogels. Zirconia and silica aerogels are used to test the concept and solve problems with these materials.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Initiating application for a Composition of Material patent.

## Planned future work

Optimize the material composition and processing, with the goals of minimum weight, maximum use temperature and sufficient strength. Reduce the density to the desired range. Perform arc-jet tests on materials, measure the thermal and mechanical properties, and compare with predicted values.

Prepared by Susan White Org. Code RTM MS 234-1 Phone (415) 604-6617



Ames Research Center

Fiscal Year 1992

## Director's Discretionary Fund Report

Title of Investigation Predicting Lyme Disease Risk: A Remote Sensing Model Based on Landscape Epidemiology

Investigator(s) (show affiliation) Byron L. Wood, James G. Lawless, Louisa R. Beck, Sheri W. Dister, Ames Research Center,  
Moffett Field, CA 94035-1000  
Durland Fish, New York Medical College, Valhalla, NY 10595

Funding	Year Initiated	FY92	Expected completion date	FY93/94
Total prior to FY92			Authorized in FY92	\$36,000
Total expended in FY92:	\$36,000	(Estimated)	Requested for FY93, if any	\$36,000
In-house	\$36,000			
Contracts (identify)				
Grants (identify)				

Status of study ☐ Completed in FY92 ☐ Terminated in FY92 ☒ Continued in FY93If continued in FY93 ☐ with funds remaining? ☒ with FY93 funds?

If transitioned to other funding, to RTOP (number?) \_\_\_\_\_

to Program (name?) \_\_\_\_\_ to Other (identify) \_\_\_\_\_

## Purpose of investigation

Develop a remote sensing-based spatial model to describe key landscape features associated with the human risk of acquiring Lyme disease in Westchester County, New York.

FY92 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Preliminary results indicate that key landscape features (deciduous forest and residential) can be correlated with canine serology (a measure of Lyme disease prevalence) by municipality in Westchester County, New York. The preliminary results to be presented at the 7th Annual Symposium on Geographic Information Systems in Forestry, Environmental, and Natural Resource Management, February 1993, in Vancouver, British Columbia.

## Planned future work

Research in FY93 will focus on analysis of the spatial patterns (i.e., location, size, shape, area, perimeter) of key landscape features (i.e., the deciduous and residential classes) associated with human Lyme disease risk. The results will provide the basis for a series of joint NASA/NYMC papers and proposals to extend the research to other areas in the United States and Europe.

Prepared by Byron L. Wood Org. Code SGE MS 242-4 Phone (415) 604-4187

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<b>13. ABSTRACT (Maximum 200 words)</b>  This technical memorandum contains brief technical papers describing research and technology development programs sponsored by the Ames Research Center Director's Discretionary Fund during fiscal year 1992 (Oct. 1991 through Sep. 1992). An appendix provides administrative information for each of the 45 sponsored research programs.				
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